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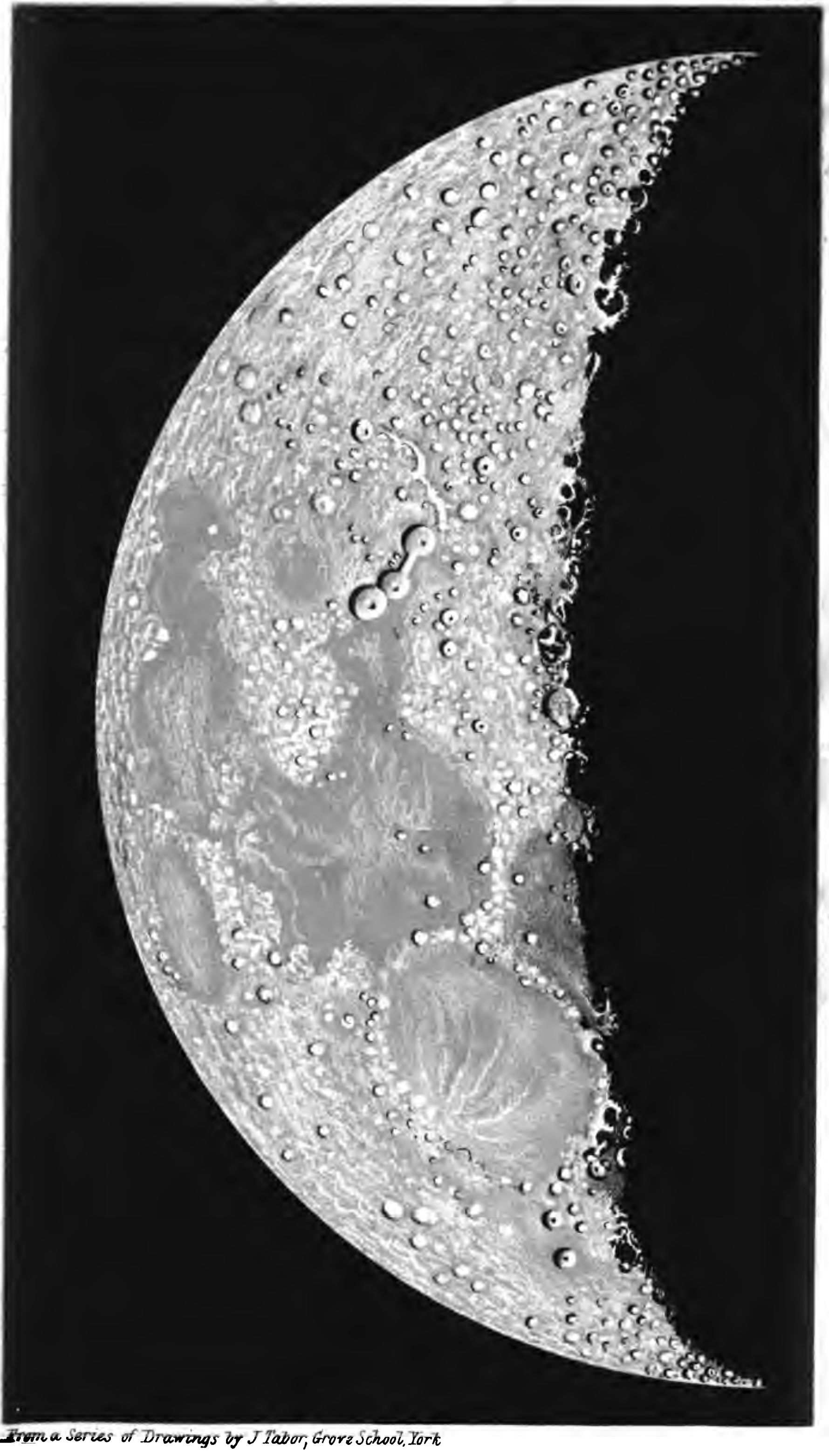
TELESCOPIC APPEARANCE OF THE MOON
a short time before Quadrature

PLATE A.



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EPITOME OF ASTRONOMY:

CONTAINING

THE INFORMATION [illegible]

AND

ASTRONOMICAL QUESTIONS

GIVEN AT THE

Class Examinations in the [illegible]

FROM ITS FOUNDATION TO THE PRESENT TIME

BY

J. TABOR,

GROVE SCHOOL, YORK.

LONDON:
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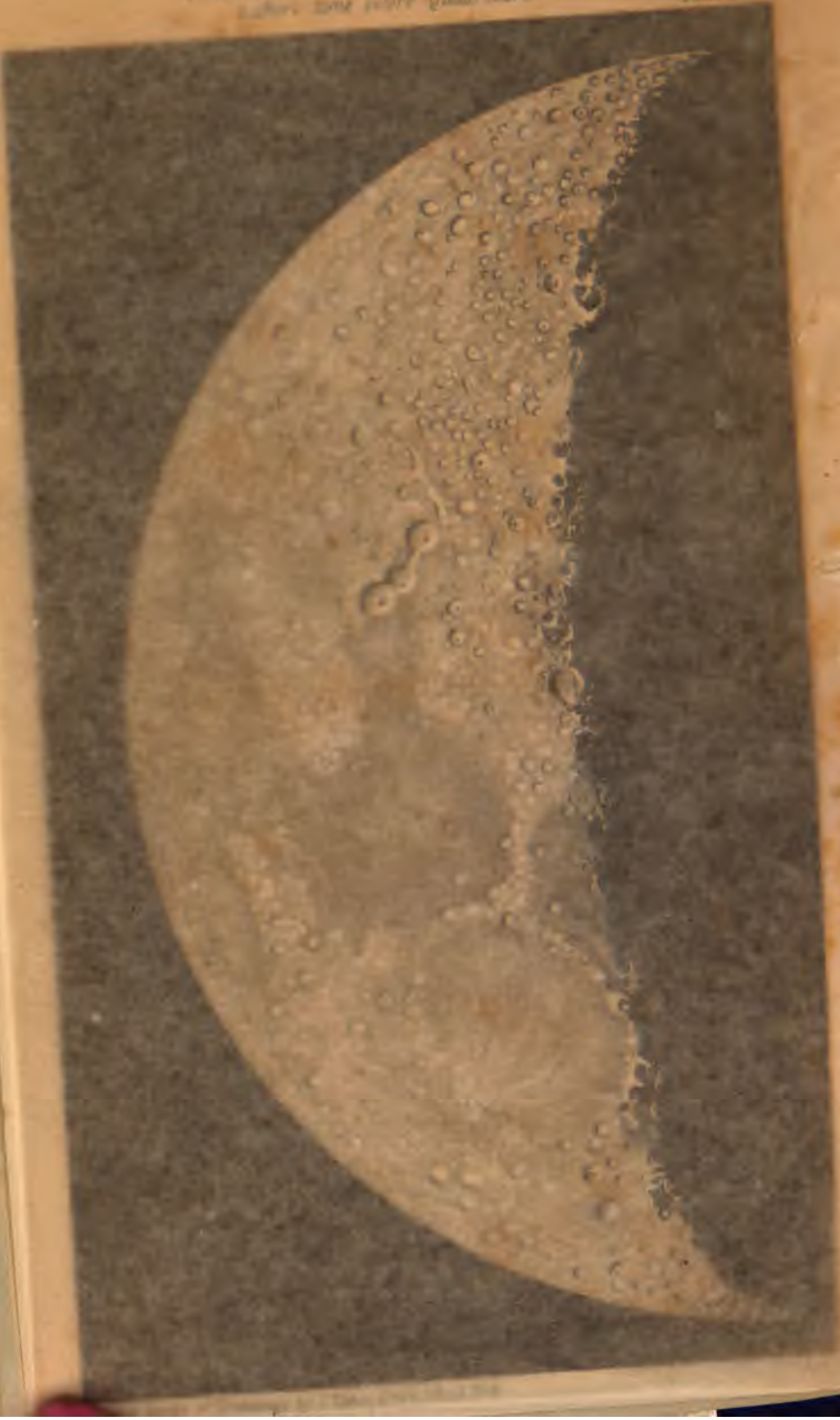
1853

TELESCOPIC APPEARANCE OF THE MOON

a short time before Quadrature

PLATE 1.



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1853

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PREFACE.

THE following pages form part of a work entitled, "An Outline of the London University Course of Mathematics, containing the Questions, Solutions," &c., and, to meet the requisitions of this title, some introductory subjects have been considerably extended, and others not strictly astronomical have been necessarily introduced.

In their preparation the most recent and popular writers have been consulted, and the whole has been as much compressed as the nature of the questions would allow, and written in as familiar a style as the character of the work of which it forms a part would admit.

GROVE SCHOOL, YORK,
June, 1853.

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CHAPTER I.

INTRODUCTION, GENERAL DEFINITIONS, &c.

INTRODUCTION.

1. THE phenomena of the heavens have engaged the attention of mankind, from the earliest ages of the world, being calculated alike to interest the mere observer and the diligent investigator; but, though the more striking celestial appearances are forced on the attention of the former, the satisfaction arising from a knowledge of their causes can only be appreciated by the latter; and though they are within the comprehension of every ordinary mind, yet the profound mathematician finds, in the science of astronomy, distances that he cannot measure and depths in infinite space that he cannot fathom; whilst the humble and contemplative Christian recognizes in the hosts of heaven the hand of his omnipotent Creator, and viewing the countless myriads of shining orbs above him in connection with his own insignificance, is led to exclaim with the Psalmist, "When I consider the heavens the work of thy fingers, the moon and the stars which thou hast ordained, what is man that thou art mindful of him, and the son of man that thou visitest him!"

2. The Chaldeans and the ancient Egyptians are amongst the first people whose astronomical observations have been transmitted to us, but since their time the science has been enriched by the discoveries of some of the greatest minds that have ever been engaged in scientific investigation; whilst, at the present day, the highest intellect, both at home and abroad, is engaged in the pursuit of this elevating study.

GENERAL DEFINITIONS, &c.

3. ASTRONOMY is the science which treats of the motions, distances, relative situations, magnitudes, &c., of the heavenly bodies, and may be divided into descriptive, physical, and practical astronomy.

4. Descriptive astronomy treats of the phenomena of the heavenly bodies; physical astronomy explains the causes of these phenomena; and practical astronomy is the investigation of these phenomena, both instrumentally and mathematically.

5. The heavenly bodies may be divided into two classes:

I. The solar system; comprising our sun, the planets with their satellites, and the comets.

II. The fixed stars; so called, because they do not perceptibly change their relative position to each other.

6. Before proceeding to the investigation of the general laws, motions, &c., of these bodies, the student should make himself quite familiar with the following definitions; for unless he clearly comprehends the circles of the sphere and their use, his future progress will be embarrassed and unsatisfactory.

7. *Circles of the sphere* are either great or small. A *great circle* is that, the plane of which passes through the centre of the sphere and divides it into two equal parts.

8. *A plane* is a surface, real or imaginary, in which any two points being taken, the straight line which joins them will be altogether in that surface or plane.

9. The equator of the earth is a great circle, the plane of which divides the earth into two equal parts, and cuts the axis at right angles; consequently it passes over all those parts of the surface which are equally distant from the poles.

10. *A small circle* does not pass through the centre of the sphere, consequently divides it into two unequal parts.

11. All parallels of latitude, the tropics, and the polar circles, are small circles, parallel to the equator.

12. *The equinoctial,* or celestial equator, is a great circle or imaginary line in the heavens, to which the plane of the terrestrial equator, if extended, would reach.

13. *The ecliptic* is a great circle in the heavens, supposed to pass over those stars before which the sun appears to move as we revolve around him. It cuts the equinoctial in two opposite points, (the beginnings of the signs Aries and Libra,) called the equinoctial points, and makes an angle with it of about 23° 27′.

14. *The zodiac* is a zone of the celestial sphere extending about eight degrees on each side of the ecliptic,—within these limits the apparent motions of the sun, moon, and planets, excepting the asteroids, or ultra-zodiacal planets, are confined.

15. The zodiac is so named from ζωδιον, an animal, because the twelve constellations contained in it, called the twelve signs of the zodiac, consist chiefly of the imaginary figures of animals, and the ecliptic which passes through the middle of it is divided into twelve equal parts corresponding to these signs. The northern signs, or those north of the equinoctial, are, ♈ Aries, the ram; ♉ Taurus, the bull; ♊ Gemini, the twins; ♋ Cancer, the crab; ♌ Leo, the lion; ♍ Virgo, the virgin. The southern signs are, ♎ Libra, the balance; ♏ Scorpio, the scorpion; ♐ Sagittarius, the archer; ♑ Capricornus, the goat; ♒ Aquarius, the water-bearer; ♓ Pisces, the fishes.

16. *The axis of a planet* is the diameter on which it rotates.

17. *The poles of the earth* are the extremities of its axis, and the poles of the heavens are the two points in the celestial sphere to which the axis of the earth, if continued, would reach.

18. *The sensible horizon* is the circle which bounds our view. *The rational horizon* is a great circle, the plane of which passes through the centre of the earth, and is extended to the heavens. It is parallel to the sensible horizon.

19. *The zenith* is that point in the celestial sphere which is directly over head.

20. *The nadir* is that point in the heavens which is opposite to the zenith, or directly under our feet. The zenith and nadir are the poles of the horizon.

21. *Vertical circles* are great circles which pass through the zenith and nadir, and are perpendicular to the horizon.

22. *The altitude* of a heavenly body is its elevation above the horizon, measured on a vertical circle.

23. *Azimuth* is an arc of the horizon contained between a vertical circle passing through a heavenly body, and the north or south point of the horizon.

24. *Amplitude* is an arc of the horizon contained between a heavenly body at rising or setting, and the east or west point of the horizon.

25. *Declination* of a heavenly body is its distance, reckoned in degrees, &c., from the *equinoctial*, north or south.

26. *Latitude* of a heavenly body is its distance from the *ecliptic*, north or south.

27. *Longitude* of a heavenly body is its distance from the *first point of Aries*, reckoned eastward in degrees, &c., on the ecliptic.

28. *Right ascension* of a heavenly body is that degree of the equinoctial which rises, culminates, or sets with it in a right sphere.

29. *Oblique ascension* of a heavenly body is that degree of the equinoctial which rises with it in an oblique sphere.

30. *Oblique descension* is that degree of the equinoctial which sets with it in an oblique sphere.

31. Right ascension, oblique ascension, and oblique descension, are reckoned on the equinoctial from the first point of Aries eastward, quite round.

32. Positions of the sphere are three, *right*, *oblique*, and *parallel*, according as the equator is at right angles, oblique, or parallel to the horizon.

33. The *orbit* of a planet is the path or course in which it moves as it revolves about the sun.

34. The *nodes* of a planet are the two points where its orbit intersects the plane of the orbit of another planet. When referred to the plane of the earth's orbit, or ecliptic, the point at which the planet crosses it to advance northward is called its *ascending* node, and the point at which it crosses to the south is called its *descending* node.

POSITIONS OF THE EQUINOCTIAL, TROPICS, &c.

35. The young student in astronomy will be greatly assisted in forming correct ideas of the circles of the sphere, if he imagine them to be visibly and permanently marked in the heavens, and

viewed from different parts of the earth, as shown in Plate I., Figs. I. and II. Thus, by observing the course of the sun from rising to setting on the 21st of March or the 23rd of September, and supposing it to be visibly traced in the heavens, one-half of the equinoctial will be truly represented, the other half completing the circle will be below the horizon towards the north. All parts of this circle will, every twenty-four hours during the whole year, rise above the east point of the horizon, and set below the west. That part above the horizon will form an arch always retaining the same altitude at the place of observation; this altitude will invariably be equal to the complement of the latitude of the place, or what it wants of 90°. Thus at London the equinoctial is always $(90^\circ - 51\frac{1}{2}^\circ)$ or $38\frac{1}{2}^\circ$ above the southern horizon. At York (lat. 54°) it is 36°.

36. Again, on the 21st of June, or the 21st of December, by supposing lines to be drawn along the course which the sun takes on these days, the tropics will be marked, the former the tropic of Cancer, the latter the tropic of Capricorn, each about $23\frac{1}{2}^\circ$ from the equinoctial.

37. An idea of the elevation of the arctic circle may be conceived, by supposing an entire circle to be drawn round the pole star, at the distance of $23\frac{1}{2}^\circ$ from it.

38. The pole star is a star of the second magnitude, in the tail of Ursa Minor. It may be readily found, by imagining a line to be drawn through the two outermost stars, commonly called the pointers, in the quadrangle of Ursa Major, and if produced to about six times their distance from each other, will terminate a little to the left of the pole star, which is about $1\frac{1}{2}^\circ$ from the pole.

39. These circles will be seen at different altitudes, according to the latitude of the place of observation. At the *equator* they all form semicircles, varying in magnitude according to their distances from the equinoctial. The equinoctial will extend from east to west, directly over head. The tropic of Cancer will rise $23\frac{1}{2}^\circ$ north of the east point of the horizon, attain an altitude of $66\frac{1}{2}^\circ$ above the northern horizon, and set $23\frac{1}{2}^\circ$ north of the west. The tropic of Capricorn will rise $23\frac{1}{2}^\circ$ south of the east, attain an altitude of $66\frac{1}{2}^\circ$ above the southern horizon, and set $23\frac{1}{2}^\circ$ south of the west. The arctic circle will form a semicircle, rising $23\frac{1}{2}^\circ$ above the north point of the horizon, the antarctic circle $23\frac{1}{2}^\circ$ above the south point, and the poles will be in the horizon.

40. Between the equator and the poles these circles vary in altitude. At $23\frac{1}{2}^\circ$ north of the equator the highest part of the tropic

of Cancer will reach the zenith. The equinoctial, tropic of Capricorn, and antarctic circle will have decreased 23½° in altitude, consequently, the antarctic circle will be just disappearing below the southern horizon.

41. In higher latitudes their respective altitudes may be readily found; for since the altitude of the equinoctial is always equal to the complement of the latitude of the place, by adding 23½° to this altitude we have the altitude of the tropic of Cancer, and by subtracting 23½° we obtain that of Capricorn.

42. These respective altitudes also show the meridian altitude of the sun on the 21st of June, when he enters the sign Cancer, and again on the 21st of December, when he enters the sign Capricorn. The meridian altitude of the sun, for any day, may be similarly found for all places between the tropics and the poles, by adding his declination for that day to the complement of the latitude of the place, when the latitude and declination are both of one kind, that is, both north or both south, and by subtracting it, when one is north and the other south.

43. Proceeding northward as far as the arctic circle, or latitude 66½°, the tropic of Capricorn entirely disappears beneath the southern horizon, and the whole of the tropic of Cancer becomes visible, as shown Plate I., Fig. II., the lowest point of it just skirting the north point of the horizon, and the equinoctial attains an altitude of only 23½° above the southern horizon. At the pole, the equinoctial will coincide with the horizon, and the tropic of Cancer will be parallel to it, at a distance of 23½°. The pole will be in the zenith, near to which is the pole star. *The elevation of the pole is always equal to the latitude of the placc of observation.* By making the obvious alterations, the same remarks are equally applicable south of the equator.

APPEARANCE OF THE HEAVENS IN DIFFERENT LATITUDES.

44. In contemplating the hemisphere of the heavens above us, the most striking phenomena are the rising and setting of the heavenly bodies.

45. A spectator in our latitude, on a clear night, looking towards the north and continuing his observation, will perceive

that many of the stars are constantly above the horizon, and revolve round the pole in circles proportioned to their respective distances from it, whilst a corresponding portion, revolving round the south pole, is constantly below it.

46. Amongst the former, the well known constellation Ursa Major is the most conspicuous. The beautiful star Vega (α Lyræ) may be observed during the evenings of February, when passing beneath the pole, just to skirt the northern horizon.

47. Directing his attention to other parts of the heavens, he will perceive some stars emerging above the eastern horizon, while others are disappearing in the west, and all describing segments of circles varying in magnitude according to their declination. Those which rise far to the north of the east, describe almost entire circles, continue above the horizon nearly 24 hours, and set as much to the north of the west as they rise to the north of the east.

48. Amongst these, the bright star Arcturus is the most conspicuous, and during the month of November may be seen approaching the north western part of the horizon, about seven o'clock in the evening.

49. Those stars which rise due east, describe semicircles, coinciding with the equinoctial, and after continuing above the horizon exactly 11h. 58 min. 2·45 sec., (half the time in which the earth performs one rotation on her axis,) set due west.

50. In the immediate vicinity of these is Orion, the most beautiful constellation in the heavens; the northern star of the three forming his belt, is in the equinoctial. To the east is Procyon, a bright star in Canis Minor, about six degrees north of the equinoctial. To the south-east of Orion is Sirius, or the dog star, the brightest star in the heavens. These are on the meridian, or due south, during the evenings of the latter part of February and the beginning of March, between seven and eight o'clock.

51. Those stars which rise south of the east describe smaller segments, remain a shorter time above the horizon, and set as much to the south of the west, as they rise to the south of the east, whilst some rise near to the southern point of the horizon, and almost immediately disappear.

52. In latitude 54° north, Fomalhaut, a bright star in the Southern Fish, attains an altitude above the southern horizon of only 5° 36′.

53. At the equator, the stars, from rising to setting, describe semicircles of various magnitudes, from that which is made by

the pole star, that rises only 1½° above the north point of the horizon, to the mighty arch described by those in the equinoctial, which rise due east, revolve with it directly over head, and disappear at the western point of the horizon; and were there no twilight, all the stars in the heavens would there be brought into view every twelve hours, as those which were rising at the instant the sun was setting, would complete their course about a minute before the sun rose the next morning; whilst the whole hemisphere of stars below the horizon, including those which were setting at the instant the sun was lost sight of, would have risen about a minute before the western limb of the sun again appeared above the eastern horizon.

54. The celestial scenery at the poles is peculiar. At the north pole, only one-half of the stars, or those that are north of the equinoctial, can be seen, the other half being *constantly* below the horizon, but visible at the south pole. The pole star describes a very small circle round the pole in the zenith; all the others describe circles round the same point, increasing in magnitude according to their distance from it; their altitude being always equal to their declination; whilst those in the equinoctial revolve with that circle in the horizon.

ILLUSTRATION BY THE CELESTIAL GLOBE.

55. After a tolerably clear conception of the circles of the sphere has been formed from the preceding definitions, &c., the globes will be found very useful auxiliaries in their illustration.

56. *For example.* The appearance of the heavens as seen from different parts of the earth may be clearly represented by the celestial globe. I. For either *pole.*—Elevate the pole until the equinoctial coincides with the horizon; turn the globe from east to west by the south, and the whole hemisphere of stars will revolve parallel to the horizon, in circles decreasing in magnitude according to their declination. II. For the *equator.*—Place both poles in the horizon, and cause the globe to rotate as before. The face of the heavens will be represented as described in Art. 53. III. For any intermediate latitude.—Elevate the pole so many degrees above the horizon as are equal to the latitude of the place. Give the globe its proper motion, and Arts. 45—52 will be clearly illustrated.

57. Again, the appearance of the face of the heavens at any place, for any *given time,* may be represented by the following rule. Elevate the pole to the latitude of the place, and bring the sun's place in the ecliptic for that day to the meridian. This position of the globe repre-

sents the face of the heavens for noon. Set the hour index to twelve, or better, note the hour and minute on the equinoctial cut by the brass meridian; then, if the given time be before noon, turn the globe eastward, or carry the sun and stars back, as many hours, minutes, &c., as the time wants of noon; but if the time be past noon, turn the globe westward as many hours, &c., as it is past noon; and the position of the globe in each case, will represent the face of the heavens for the given time. All the stars on the eastern semicircle of the horizon are rising, those coinciding with the graduated edge of the brass meridian are culminating, and those on the western semicircle of the horizon are setting.

58. If the globe, in this position, be taken out of doors and placed due north and south, and the flat end of a pencil be placed on any star, so as to point to the centre of the globe, the other end of the pencil will be directed to the corresponding star in the heavens. In this way a familiar acquaintance with the constellations may very soon be obtained. *For example:* To ascertain what constellations are above the horizon at York, at eight o'clock in the evening, on the first of January. Having rectified the globe for the latitude, (54° north,) and the sun's place (10½° in Capricornus) being brought to the meridian, set the index to twelve, or note the hour and minute on the equinoctial cut by the brass meridian. Then, as the time is past noon, turn the globe from east to west on its axis, until the brass meridian has passed over eight hours, either on the index or the equinoctial, and on examining the globe it will be found that the constellation Leo is rising a little to the north of the east; the bright star Regulus is just appearing above the horizon; Sirius in Canis Major is a few degrees above the horizon, towards the south; and that Orion, Taurus, and Gemini have attained a considerable altitude. Algol in Perseus and Menkar in Cetus are near the meridian, and the two principal stars in Aries are a little to the west of it. Vega (α Lyræ) and Arided (α Cygni) are approaching the north-western part of the horizon; whilst the constellations Aquila, Aquarius, and others, are just disappearing below it. By placing one end of a pencil on these stars, its other end will be directed to the real stars in the heavens.

DIFFERENT SYSTEMS OF ASTRONOMY.

59. An attentive observer will not continue his observations long, before he will perceive, that, though the stars generally retain the same relative situation with respect to each other, some of them, even in a few weeks, sensibly change their places, and are moving, sometimes towards the east and sometimes towards the west; these are called planets, from πλανητης, a Greek word signifying a wanderer. The ancient astronomers observed these motions, and in order to account for them formed several systems

of astronomy, most of them, however, adapted to their own preconceived opinion, "that the earth was at rest, and that the sun, moon, planets, and stars revolved round it."

60. The most celebrated of these systems are the Pythagorean, afterwards revived by Copernicus, and the Ptolemaic. The ancient Egyptians, aware of the proximity of Mercury and Venus to the sun, supposed that these planets had the sun and not the earth for their centre; but Pythagoras, who lived about 500 years before Christ, taught the great truth that "the sun is the centre, round which the earth and the other planets revolve." Succeeding philosophers, however, rejected this theory, amongst whom were Plato and Aristotle.

61. Ptolemy, a celebrated Egyptian, flourished about A.D. 130; and in the system named after him, the earth is supposed to be stationary, and to be in the centre of the universe, the entire heavens revolving about it in twenty-four hours. This system was adopted by most of the celebrated philosophers and astronomers for nearly fourteen centuries, until Copernicus, about A.D. 1530, revived the true doctrine taught by Pythagoras.

62. A few years afterwards, Tycho Brahe, a Swede by birth, but at that time living in Denmark, struck with the simplicity and harmony of the Copernican system, yet blindly attached to the old doctrine, invented a very ingenious system to account for the motions of the planets, and yet retain the popular idea that the sun moved round the earth. But none of these systems were able to bear the test of scientific investigation except that of Copernicus, the truth of which has been fully demonstrated by Kepler, Galileo, Newton, and others, and to which we shall now direct our attention.

CHAPTER II.

GENERAL VIEW OF THE SOLAR SYSTEM.

63. THE solar system consists of the sun, round which the planets with their satellites, and the comets revolve in periods proportioned to their respective distances.

64. The centre of gravity of the whole solar system, and not the sun's centre, is the true point round which the planets revolve. This point, however, owing to the enormous mass of the sun, is always within his body, and the centre of the sun revolves about it, at various distances, according to the positions of the planets in their orbits with respect to the sun.

65. Attempts are frequently made to represent the solar system by means of diagrams and orreries, which, however large, altogether fail to give any adequate idea of the comparative magnitude of the sun, or the distances of the planets; for should the former be represented by a globe twelve inches in diameter, some of the latter must be represented by grains so small as to be scarcely perceptible, yet placed in orbits varying in diameter from 82 feet (the comparative diameter of the orbit of Mercury) to more than a mile, which on this scale would represent the orbit of Neptune.

THE SUN.

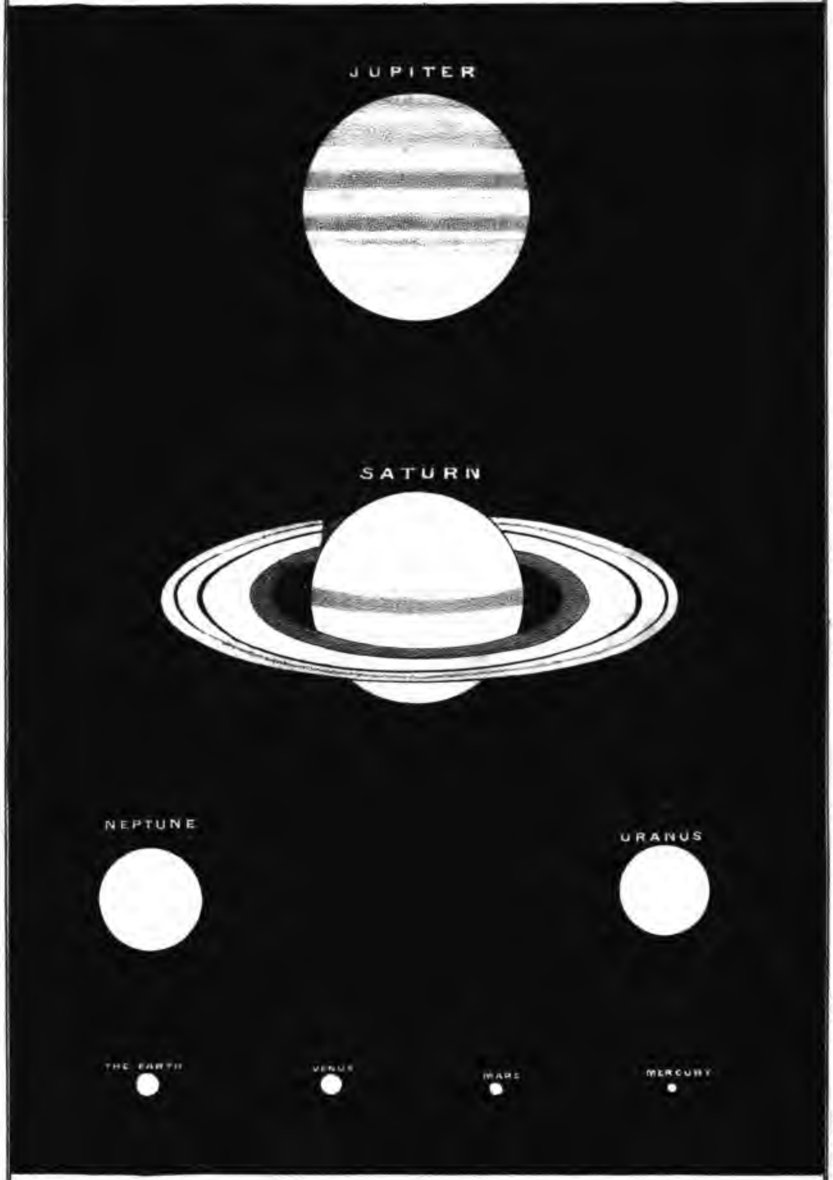
66. This vast globe, the source of light, heat, and life to the whole solar system, is found by the latest measurements to be about 887,076 miles in diameter, or so large, that if it were a hollow sphere, and the earth placed in the centre, there would be far more than sufficient room in it for the moon to revolve round the earth, even were her distance nearly twice as great as it really is.

67. When viewed through a telescope the sun does not appear uniformly bright, but has a mottled appearance. About his equatorial regions large irregular dark spots are generally to be seen on the surface, varying in magnitude from the size of Great Britain, the least area that can be distinctly perceived from the earth, to that of the continent of Asia or America, and in some instances exceeding even the area of the whole earth. The central part of these spots, called the nucleus, is dark or black, but the part immediately surrounding it, called the penumbra, is not so deeply shaded. Bright streaks, called faculæ, are generally seen in the vicinity of the large spots, and have been supposed to be the ridges of vast waves, produced by some violent disturbance of the luminous atmosphere of the sun.

68. Various conjectures have been formed respecting these spots, but the most probable opinion is, that they are the body of the sun itself, appearing through openings by some means produced in the luminous atmosphere.

69. Like the planets, the sun also revolves on his axis in about 25 days; this is ascertained by observing the time which is occupied by a solar spot in passing over his disc. The sun is also supposed by Herschel and other astronomers to have another motion through space, carrying with it the planets, &c. This motion is thought to be towards the constellation Hercules.

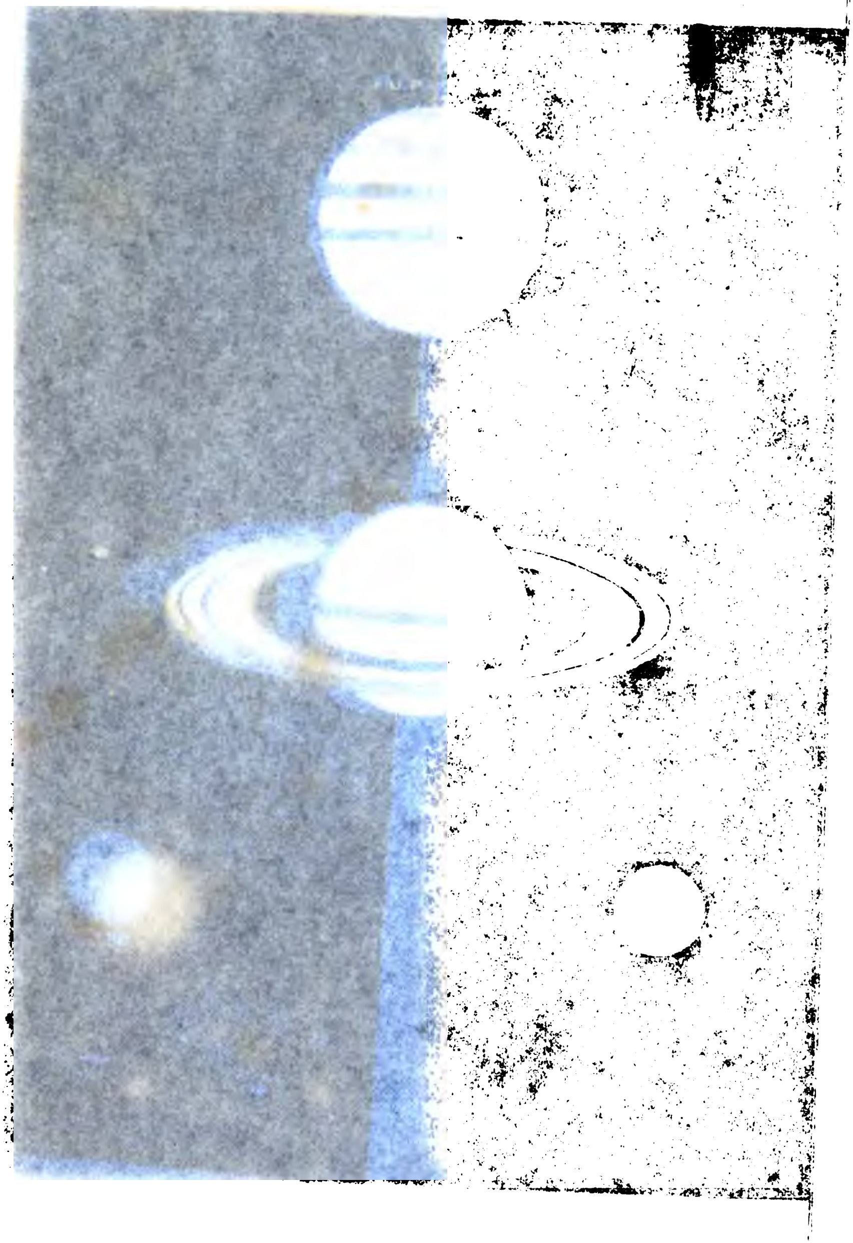
COMPARATIVE SIZES OF THE PLANETS.



THE SUN A GLOBE TWELVE INCHES IN DIAMETER.

See Article 65

SIZES OF THE PLANETS



SMALLER

THE PLANETS AND THEIR SATELLITES.

70. Though several of the planets exceed the fixed stars in brightness, they are opaque bodies, and shine only by reflecting the sun's light; this is known by their presenting phases similar to those of the moon, and which are most obvious to us in the planets Mercury and Venus.

71. One of the strongest arguments brought against the system of Copernicus was, that if true, Mercury and Venus ought to present phases like those of the moon. This Copernicus admitted, and expressed his firm conviction that such was the case, and about fifty years after his death the invention of the telescope revealed the truth of his assertion, and contributed to establish his system.

72. The planets are divided into primary, minor primary, and secondary.

73. The *primary planets* at present discovered are, Mercury, Venus, the Earth, Mars, the Minor Primaries, Jupiter, Saturn, Uranus, and Neptune.

74. The *minor primary* planets, so called on account of their diminutive size, move between the orbits of Mars and Jupiter; of these, Ceres, Pallas, Vesta, and Juno, were discovered during the first eight years of the present century. Since that period many others have been discovered, but they are all so minute as to be invisible to the naked eye. They are also called ultra-zodiacal planets, because their orbits make an angle of more than 8° with the ecliptic.

75. The *primary* planets are also divided into inferior and superior. Mercury and Venus are called inferior planets, because their orbits are nearer to the sun than that of the earth; all the others are called superior planets, because their orbits lie beyond that of the earth. Planets that are near the sun move more rapidly in their orbits than those that are remote. Mercury proceeds in his orbit at the rate of 1800 miles per minute, whilst Uranus does not move more than 240 miles in the same time.

76. *Secondary planets,* or satellites, are those which revolve about a primary planet, and accompany it in its revolution round the sun.

when viewed from the earth, they appear sometimes to move from east to west amongst the fixed stars, sometimes from west to east, and sometimes to remain for a short time stationary.

87. When a planet, as seen from the earth, appears in the same part of the heavens, or exactly in the same sign and degree of longitude, as the sun, it is said to be in conjunction with the sun. When in the sign and degree exactly opposite to the sun, it is said to be in opposition.

88. Mercury and Venus have each two conjunctions. When either planet is between the earth and the sun, as at *e*, Plate II., Fig. I., it is in its inferior conjunction; when in that part of its orbit which is beyond the sun, as at *g*, it is in its superior conjunction; but as these planets are within the orbit of the earth, neither of them can be in opposition to the sun.

89. The sidereal revolution of a planet is the time which it occupies in making an entire revolution round the sun. The synodical revolution of a planet is the time occupied between two consecutive conjunctions with the sun.

90. The inclination of the axis of a planet to the plane of its orbit, is the angle which the axis makes with a perpendicular to that plane, and it is this inclination of the axis that produces the variety of the seasons.

91. The axis of the earth, Plate I., Fig. VI., inclines 23½° from the perpendicular *ab;* the axis of Venus, Fig. V., inclines 73°; that of Jupiter, Fig. VII., only 2°, being nearly *perpendicular* to the plane of his orbit, whilst the axis of Venus is nearly *parallel* to the plane of her orbit.

COMPARATIVE DENSITIES OF THE PLANETS.

92. Though many of the planets are so much larger than the earth, yet their mass, that is, their weight or the quantity of matter they contain, is not in proportion to their size.

93. The respective densities of the planets have been ascertained by comparing their magnitudes with the power of attraction which they exert on the other planets. Thus, if the density of water be taken as 1, the density of the sun will be about $1\frac{1}{4}$; of Mercury, $9\frac{1}{8}$; of Venus, $5\frac{1}{15}$; of the earth, 5; of the moon, $3\frac{1}{2}$; of Mars, $3\frac{1}{4}$; of Jupiter, $1\frac{1}{24}$; of Saturn, $0\frac{18}{32}$; of Uranus, $0\frac{99}{100}$.

94. According to the above, the weight of the sun is a little more than it would be if it were formed entirely of water; whilst that of the earth is rather more than five times heavier than water, or about twice as heavy as if it were composed of solid rock; thus proving that the interior of the earth must consist of materials much heavier than that part of its surface with which we are acquainted. Saturn and the remote planets are not heavier than they would be if composed of light wood.

MERCURY.

95. This is the nearest planet to the sun, and derived his name from the rapidity of his orbitual motion, being called Mercury by the ancients, from a supposed similarity between his rapid motion and that of the messenger of the gods. He is situated at the mean distance of 36,890,000 miles from the sun, round which he revolves in 87 days, 23 hours, 15 min., 43·9 sec., at the enormous rate of about 1800 miles per minute, but it has not yet been satisfactorily ascertained whether he rotates on his axis. The diameter of Mercury is about 2950 miles, and in consequence of this diminutive size, and his proximity to the sun, he is seldom seen by the naked eye, and then only during a few days, either just after sunset, or just before sunrise. Mercury is never seen more than 29° from the sun, and owing to the great eccentricity of his orbit, his greatest elongation is sometimes reduced to little more than 16°.

96. Whilst passing his inferior conjunction with the sun, he is sometimes seen to traverse the disc of that luminary like a black spot. This is called a transit of Mercury, and can only happen when he is in one of his nodes, and that node in a direct line between the earth and the sun.

VENUS.

97. Venus is the second planet in order from the sun, and is nearly as large as the earth, her diameter being about 7,900 miles. She is situated at the mean distance of 68,770,000 miles from the sun, is the most brilliant of all the planets, and may sometimes be seen by the naked eye at noonday. The most favourable time for viewing her through the telescope is in a tolerably strong twilight, but she is at all times a difficult telescopic object. Venus revolves round the sun in 224 days, 16 hours, 49 min., 8 sec.,

and rotates on her axis in about 23 hours, 21 minutes. Her axis is supposed to make an angle of about 73° with a perpendicular to the plane of her orbit, consequently she has great diversity of seasons, her tropics being only 17° from her poles, and her polar circles but 17° from her equator. (See Plate I., Fig. V.)

98. This planet seldom passes directly between the sun and the earth, therefore a transit of Venus is of rare occurrence, but is of great use in practical astronomy, in determining the sun's horizontal parallax, from which the distance of the earth from the sun is ascertained, and from this, the distances of the other planets, (Art. 80.)

THE ELONGATIONS, DIRECT AND RETROGRADE MOTIONS OF THE INFERIOR PLANETS, MERCURY AND VENUS.

99. Mercury and Venus, like the other planets, if viewed from the sun, would always be seen to move from west to east; and if the earth were stationary, and they were viewed from it, they would appear to have an oscillatory motion, and to make vibrations from the sun each way, alternately passing before and behind the sun; their stationary points would always be nearly in the same places in the heavens, and their direct and retrograde motions equal.

100. Let *V W* (Plate II., Fig. I.) represent an arc of the heavens, *S* the sun, *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, Venus in different parts of her orbit, and *E* the earth. Suppose Venus to be at *a*, and the earth at rest at *E*, then the line forming one side of the angle of distance between Venus and the sun is a tangent to her orbit, consequently in this situation she is at her greatest elongation eastward of the sun, is an evening star, and for a time appears stationary at *V*. As Venus proceeds from *a* towards *c*, or approaches her inferior conjunction, her motion is *retrograde*, or contrary to the order of the signs. At *b* she appears at *b'*, and presents a beautiful crescent in the evening sky, similar to that of the moon three or four days after the change. When arrived at *c*, she is in her inferior conjunction with the sun, and the whole of her dark side being turned towards the earth, she is invisible to us, unless she is in one of her nodes, when she appears like a black spot traversing the disc of the sun. At *d* she appears west of the sun at *d'*, is a morning star, rises before the sun, and exhibits a crescent similar to that which she presented when at *b*. When at *e*, she has attained her greatest elongation west of the sun, again appears stationary at *W*, and from this point her *direct* motion begins. Proceeding in her orbit

to *f*, she is again seen in the heavens at *d'*. Much more of her enlightened side is now turned towards the earth, but being at a greater distance from us than when at *d* or *e*, she is not so brilliant. At *g*, her superior conjunction with the sun, the whole of her enlightened surface is towards the earth, but invisible to the unassisted eye, being lost in the beams of the sun.* Moving from *g* to *h*, she appears to go from *c'* to *b'*, and proceeding to *a*, again appears stationary at *V*.

101. Such would be the appearance of an inferior planet to us, as it revolved round the sun, if the earth remained at rest at *E;* but this is not the case, for whilst the planet is proceeding in its orbit, the earth is also proceeding in hers, and in the same direction.

102. In consequence of the orbitual motion of the earth, Venus is a *morning star*, or appears west of the sun for 290 days, and an *evening star*, or appears east of the sun for nearly the same length of time.

103. This motion of the earth, however, does not materially affect the different aspects of the planets, as regards phases, direct and retrograde motions, &c., but causes these appearances to continue for a longer period and to take place in different parts of the heavens.

104. *For example.*—The positions of Venus as given in the ephemeris for the year 1852 are: "May 12th: Venus attains her greatest elongation (45° 23') east of the sun. June 28th: Venus stationary. July 21st: Venus in inferior conjunction with the sun. August 11th: Venus stationary. September 30th: Venus attains her greatest elongation (46° 11') west of the sun."

Suppose Venus, on the 12th of May, to be at *V*, (Plate II., Fig. II.,) at her greatest elongation east of the sun; consequently the earth on the same day was at *E*, and Venus appeared in the heavens at *V'*, and if the earth remained at rest, this would have been the stationary point of Venus (as in Plate II., Fig. I.); but as the earth was also proceeding in her orbit, Venus was not stationary until more than six weeks after, or until she arrived at *w* on the 28th of June, at which time the earth was at *f*, and Venus appeared stationary at *w'*; her geocentric longitude being then about 6¼° in Leo, several degrees east of the position she occupied when at her greatest elongation at *V;* and from this point *(w')* her *retrograde* motion commenced. Passing her inferior conjunction with the sun at *x*, (July 21st,) she arrived (August 11th) at *y*, and again appeared stationary at *y'*, her geocentric longitude being about 21° in Cancer. From this point her *direct* motion commenced, and will continue until she again reaches her stationary point east of the sun. Proceeding in her orbit to *z*, at which time the earth was at *i*, Venus appeared in the heavens at *z'*, and attained her greatest elongation west of the sun. Thus the motion of an inferior planet is *direct* from its stationary point *west* of the sun to its stationary point east of the sun, or whilst passing its superior conjunction; and *retrograde* from its stationary point *east* of the sun, to its stationary point west of the sun, or whilst passing its inferior conjunction. It will be evident from the figure, that Venus appeared to retrograde through the arc, *w' y'*, or about 16°, her mean arc of retrogradation.

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* Dr. Dick records several telescopic observations of Venus, when very near her superior conjunction with the sun.

THE EARTH AND MOON.

105. The earth is, to us who dwell on its surface, the most important of all the planets; and we seek an acquaintance with the others chiefly that we may ascertain the figure, dimensions, and movements of our own.

ANNUAL MOTION OF THE EARTH.

106. The earth is situated at the mean distance of 95,298,260 miles from the sun, round which she revolves in 365 days, 6 hours, 9 minutes, 10·7 seconds, the length of her *sidereal* year.

107. The orbit of the earth, like that of all the other planets, is elliptical, having the sun in one of the foci; consequently she is nearer the sun when in one part of her orbit than when in another.

108. This is proved by the apparent diameter of the sun being greatest when the earth is nearest to him, and least when at her greatest distance. Thus on the 1st of July, when the earth is in aphelion, at *a*, (Plate I., Fig. III.,) or at her greatest distance from the sun, his apparent diameter is 31′ 30″; whilst on the 31st of December, when in perihelion at *A*, or at her least distance, his apparent diameter is increased to 32′ 34·6″. It is also ascertained from the most accurate measurements, that the apparent daily angular motion of the sun in the heavens is greater at one season than at another, arising from the unequal velocity of the earth's motion in her orbit. According to Kepler's second law, "the planets describe equal areas in equal times;" it therefore follows, that when the apparent angular motion of the sun is greatest, the earth must be in that part of her orbit which is nearest to him, and when his apparent daily angular motion is least, she must be at her greatest distance.

109. By the revolution of the earth round the sun the latter has an apparent annual motion amongst the fixed stars, as more fully explained, (Art. 176 to 183,) and the period that elapses between the sun's departure from any fixed star to his return to it, is called a *sidereal* year.

110. The *tropical* year is the time in which the sun appears to move from one equinox to the same equinox again, and consists of 365 days, 5 hours, 48 minutes, 47·8 seconds, which period is also called the *natural* year, because on it depends the return of the seasons. It is 20 min. 22·9 sec. shorter than the true sidereal

year, owing to the retreat of the equinoxes along the ecliptic, (Art. 184 to 187,) which amounts very nearly to 50·25″ of a degree in a year, and to pass over this arc the sun requires 20 min. 22·9 sec. of time.

111. The *civil* year consists of 365 days, or if leap year, of 366 days. The *tropical* year, as above stated, consists of 365 days and a fraction of a day, but for convenience the *civil* year is made to contain an exact number of days; therefore to adjust it to the tropical year, one day is added to every fourth year, which year is called *leap year,* and consists of 366 days.

112. The axis of the earth (see Plate I., Fig. VI.) makes an angle of 23° 27′ 36·5″ with a perpendicular to the plane of her orbit, and during her whole course round the sun it preserves this inclination, and is also constantly directed to one point in the heavens called the pole. (See Art. 185.) This inclination of the axis produces that agreeable variety of seasons which we enjoy, and also the different lengths of day and night.

113. Were the axis of the earth perpendicular to the plane of her orbit, as is nearly the case with that of Jupiter, (Plate I., Fig. VII.,) her equatorial regions would be constantly scorched by the direct rays of a vertical sun, whilst the polar regions would be enveloped in perpetual ice and snow; and only those parts about midway between the equator and the poles would be fit for the habitation of man.

DIURNAL MOTION OF THE EARTH.

114. The earth rotates on her axis in 23 hours, 56 minutes, 4·9 seconds, which is a true sidereal day, and is subject to no sensible variation. It is reckoned from the time of any *fixed star* being on the meridian of any place, till it returns to it again.

115. A solar day is about 4 minutes longer than a sidereal day, and consists of the time which elapses from the *sun* being on the meridian of any place, on any day, until he returns to it again.

116. The difference between a solar and a sidereal day will be readily understood from Plate III., Fig. I., where *S* represents the sun, and *m* a place on the surface of the earth, the meridian of which at a certain time coincides with the sun and some fixed star.* When the earth is

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* The fixed stars are at such an immense distance from us, that all lines supposed to be drawn from any fixed star to the earth, though in different parts of her orbit, are considered to be parallel.

at A, the sun and the star are on the meridian of the place at the same instant, and in the course of 23 hours, 56 minutes, 4·9 seconds, this would be the case again if the earth were stationary, but during that time she has been proceeding in her orbit from A to A', and though the meridian of m is again brought to coincide with the star, and the earth has performed an entire revolution on her axis, yet the sun appears nearly a degree to the *east* of the meridian of the place; the earth therefore must rotate about 4 minutes longer, or until m arrives at m', before the sun will again be on the meridian.

117. The length of the solar day is subject to a continual variation, arising from the unequal motion of the earth in her orbit, and from the obliqity of the ecliptic; it is sometimes more than 24 hours, and sometimes less. A mean solar day is the portion of time that intervenes between two consecutive noons as shown by a well regulated clock, and is of the average length of 24 hours; consequently it is not always exactly 12 o'clock, mean time, when the sun is on the meridian of any place.

118. When the sun comes to the meridian of a place, or properly speaking, when the plane of the meridian of any place coincides with the sun, it is said to be apparent noon at that place, and also at all places under the same meridian.

119. The earth, by rotating on her axis from west to east, gives to the sun his apparent westward course round the earth, and thus brings the meridian of any place round to the sun, on an average every 24 hours; therefore $\frac{360^\circ}{24} = 15^\circ$, the space of the earth's surface passed over by the sun in one hour, or one degree for every four minutes of time. Hence the following rules: Difference of longitude in degrees divided by 15 gives hours, or multiplied by 4 gives minutes, either earlier or later, as the place at which the time is required is west or east of the place at which the time is given.—Difference of time in hours multiplied by 15 gives degrees of longitude, or difference of time in minutes divided by 4 gives degrees of longitude east or west, according as the time for which the place is required is later or earlier than the time of the given place. *Example.*—At 10 o'clock, A. M., at Greenwich, in what latitude is it midnight? Here the difference between the time given and the preceding midnight at Greenwich is 10 hours, ∴ 10 × 15 gives 150 degrees; and since at all places east of Greenwich it is later in the day than at Greenwich, so at all places west of Greenwich it is earlier, therefore when it is 10 o'clock A. M. on any day at Greenwich, it is midnight at all places having 150 degrees west longitude.

120. At the equator, the days and nights are equal, each being twelve hours long during the whole year. At the poles, the sun is alternately visible and invisible for six months together. At all other parts of the surface of the earth, the days and nights are of unequal lengths, except at the times of the equinoxes.

121. The above may be illustrated by the terrestrial globe, and also the position of the earth as regards sunlight may be represented for any given day and hour. *Rule.*—If the sun's declination be north, elevate the north pole of the globe so many degrees above the horizon as are equal to the sun's declination on that day; if south, elevate the south pole.* Bring the place at which the time is given to the brass meridian, and set the index to twelve. This position of the globe represents the earth as regards sunlight when it is noon at that place. To all places above the horizon it is day; to all places more than 18° below, it is night; to those less than 18° below, it is twilight. To all places coinciding with the upper semicircle of the brass meridian it is noon, to all those coinciding with the lower semicircle it is midnight. To all places along the *western* horizon the sun is rising, and to those just sinking below the *eastern* horizon the sun is setting. For any other hour; cause the globe to rotate from west to east until the index have passed over so many hours as the given time is past noon, and the globe will represent the position of the earth for that time. It will be observed, during the rotation of the globe, that a portion of the earth's surface round the elevated pole, to a distance equal to the declination of the sun, does not descend below the horizon, and consequently enjoys continual day; whilst a corresponding portion about the opposite pole never comes into sunlight.

122. The earth rotates on her axis from west to east with a perfectly smooth and uniform motion, carrying with her the atmosphere, clouds, &c.; thus producing the alternations of day and night, and the apparent rising and setting of the heavenly bodies.

123. The fact that this motion is not felt is no argument against the truth of it. A person sitting in the cabin of a ship which is moving smoothly through the water, is quite unconscious of his own progressive motion, or of that of the vessel, but on looking out of the window he attributes motion to the trees, houses, and other objects on shore, which appear to be moving or passing in a contrary direction; and it is said that Copernicus, from observing similar instances of relative motion amongst terrestrial objects, was first led to think that the apparent diurnal revolutions of the heavenly bodies were produced by the real motion of the earth in an opposite direction.

124. It is true, that if the heavenly bodies moved round the earth in twenty-four hours, whilst the earth remained at rest, the same appearances would be presented that are produced by the rotation of the earth on her axis; but to accomplish this, the sun, which is more than a million times larger than the earth, and ninety-five millions of miles distant, must, every twenty-four hours, perform a circuit of nearly 600,000,000 of miles, or more than 4,000,000 of miles per minute. Yet, inconceivable as this rapidity is, it is slow when compared with the velocity with which the fixed stars would have to move, to accomplish a revolution round the earth in the same time.

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* The declination of the sun for any day may be found either from an ephemeris, or by bringing the sun's place in the ecliptic for the given day to the brass meridian of the globe, then the degree immediately over the sun's place shows the declination, north or south.

THE FIGURE OF THE EARTH.

125. The figure of the earth is globular, though not perfectly spherical, being an oblate spheroid.

126. Her globular figure is proved from the circular form of her shadow thrown on the moon during an eclipse, in whatever position it may be projected, since no other body than a sphere can, in every position, cast a circular shadow.

127. Again.—The greatest distance to which a person of ordinary stature can see the surface of the ocean, when standing on a level with it, is about three miles; therefore, when a vessel leaves the coast and sails in any direction, and in any part of the world, for the first three or four miles of her course, the whole of the hull to the water line is seen by a spectator from the beach at *A* (Plate III., Fig. II.); but as soon as she passes the *sensible* horizon at *B*, the lower part of the hull disappears, being hid by the curvature of the surface of the water, as shown at *B'*. When at *C*, the hull has entirely disappeared, as at *C'*; at *D*, the lower sails are lost sight of, as at *D'*; at *E*, nothing remains in sight except the flag, as at *E'*; and as the vessel proceeds, this also soon disappears, though distinctly seen through a telescope until it apparently sinks below the water.

128. Again.—At the equator the celestial pole is in the horizon, but proceeding northward we change our horizon, and see as many degrees beyond the pole as we have advanced towards it, and consequently the pole star increases an equal number of degrees in altitude, whilst the stars which were seen towards the south gradually decrease in altitude until they disappear beneath the southern horizon.

129. The mean diameter of the earth is 7912·4 miles; the polar diameter being 7899·2 miles, and the equatorial 7925·6 miles.

130. The *spheroidal* figure of the earth has been proved by the gradual increase in the length of a degree of latitude, in proceeding from the equator to the poles. Also, from the unequal vibrations of pendulums in different latitudes. A pendulum that is made to vibrate seconds in the latitude of London, moves more quickly when removed nearer to the pole, and more slowly as it approaches the equator. At the equator it requires to be shortened about one-third of an inch, thus showing a diminution in the force of gravity, arising chiefly from the increase of centrifugal force, but partly also from being at a greater distance from the centre of the earth.

131. The earth is surrounded by a fluid called the atmosphere, which gravitates towards the earth, revolves with her in her diurnal motion, and accompanies her in her revolution round the sun. It extends to an unknown, but in all probability, not to an indefinite height.

TRADE WINDS.

132. When the atmosphere is put in motion it is called wind, and heat is the principal agent in producing this motion.

133. During the day the earth's surface is continually receiving heat from the sun, but especially those parts which are exposed to his vertical rays. The tropical regions of the earth, therefore, being greatly heated, communicate heat to the superincumbent atmosphere, which is thereby expanded and rendered much lighter than the air immediately above it, consequently it ascends and flows over the denser air towards each pole, whilst the air from the cooler regions of the earth rushes in from both sides to supply its place.

134. The tropical regions of the earth, and consequently the atmosphere, clouds, &c., are carried from west to east, by the rotation of the earth on her axis, at the rate of from nearly 900 to 1000 miles per hour, varying according to the distance from the equator. This rate of motion diminishes towards each pole, therefore the cool air which rushes in to supply the place of that which has ascended, coming from parts of the earth which are not carried from west to east at such a rapid rate as the parts over which it is now flowing, revolves more slowly, and objects on the surface of the earth near the equator, being carried forward from west to east more rapidly than this current of cool air, rush against it and experience an easterly wind; but the cool air, in its passage towards the parts which are most heated, gradually acquires greater eastward velocity by its friction against the earth's surface, and at length moves as rapidly in an eastward direction as those parts over which it is flowing, and its course is then nearly north and south towards the vacant space it is rushing to fill.

135. These trade winds prevail from near the equator to about 28 or 30 degrees north or south of it, varying a little, according as the sun has north or south declination.

136. Capt. Basil Hall remarks, that on entering the trade wind, either from the north or south, it blows very nearly due east; but on approaching the equator from the north, it gradually draws round from east to north-east, and even to the north at the southern margin of the north-east trade wind. The equatorial limit of the trade wind varies with the season of the year; and between the N. E. and the S. E. trade winds there is a zone of from 150 to 500 miles in breadth, technically called the calms and variables.

THE [illegible]ON

[illegible] timate of the earth. [illegible] has been [illegible] curiosity of [illegible] interesting.

[illegible] of the [illegible] are not [illegible] Plates [illegible]

[illegible] as they [illegible] of a cement [illegible] simple form, having [illegible] the [illegible] of which [illegible] height [illegible] circumference is somewhat [illegible] perfect; but [illegible] and the whole [illegible] comparatively small cavities [illegible] craters are generally very circular hollows, with flat floors, some of them [illegible] general surface of the [illegible] elevated [illegible] thousand feet.

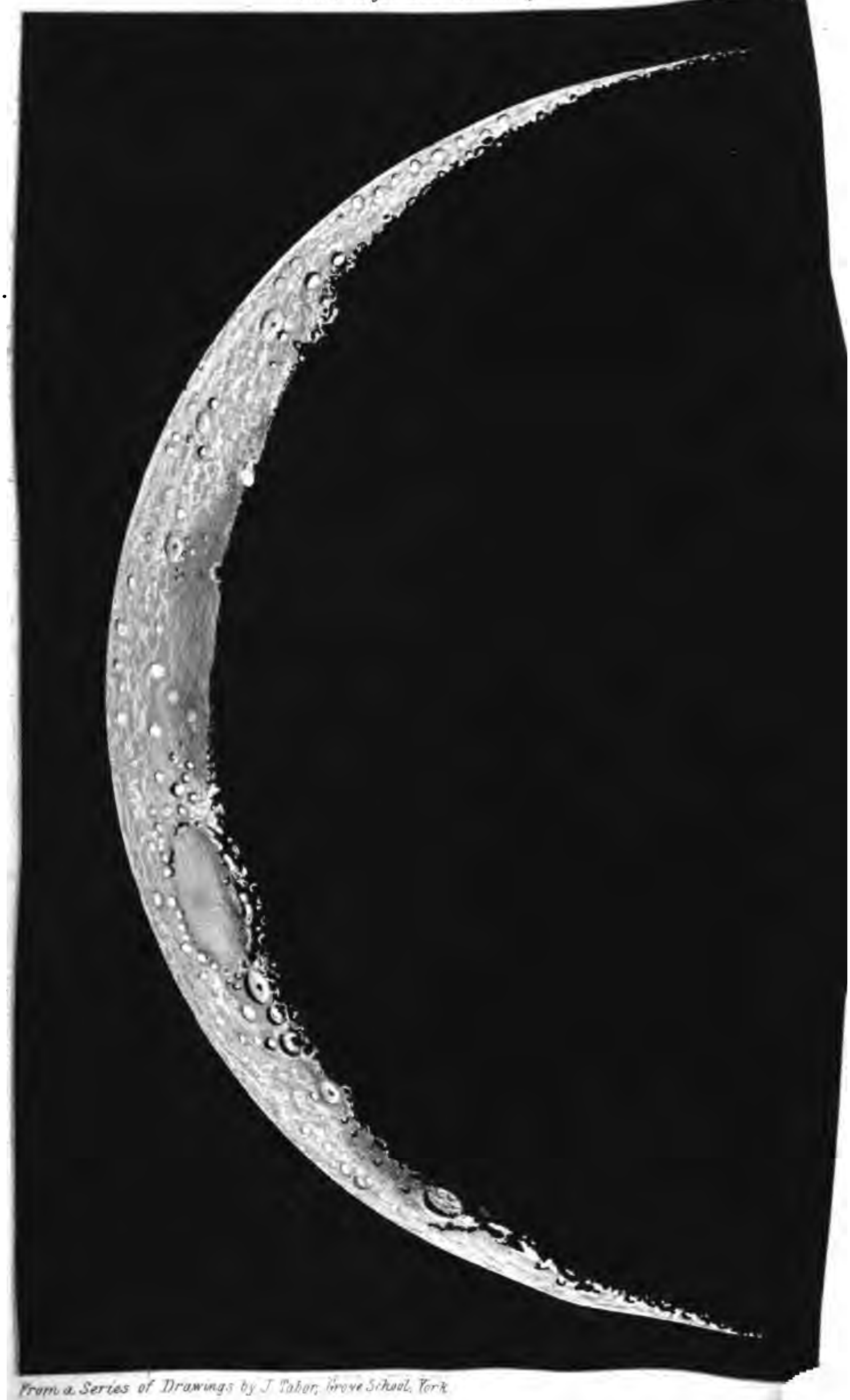
[illegible] by a modern [illegible] the [illegible] particular [illegible]

[illegible] the moon's surface [illegible] Herschel remarks [illegible] perfectly [illegible] and [illegible]

PLATE C.

TELESCOPIC APPEARANCE OF THE MOON

a few days after the change.



From a Series of Drawings by J. Tabor, Grove School, York.

142. The moon is supposed to be entirely destitute of water, and if possessed of an atmosphere it must be exceedingly rare, otherwise it would produce phenomena which the most attentive observers have never yet been able to detect.

143. That the moon has either no atmosphere, or no water, is evident from the fact, that the surface of the moon is always clear and bright, whenever our own atmosphere is unclouded. Were there water, and also an atmosphere sufficiently dense to bear the vapour which would be raised during the fortnight of continued sunshine, clouds would undoubtedly be formed, which would at times obscure the face of the moon; and the condensed vapour on the confines of the cold, dark hemisphere would be detected by gradually diminishing the light of faint stars, immediately before their occultation by the moon. This, however, has never been perceived by the most careful observers.

144. The moon is 2160 miles in diameter, and is situated about 238,650 miles from the earth, round which she revolves* in 27 days, 7 hours, 43 minutes, 11·461 seconds, which period is the length of her sidereal revolution, and in this time she rotates on her axis; this is ascertained from the fact, that she always presents the same side to the earth. This period is 6·847 seconds longer than her tropical revolution, arising from a slow retrograde movement of the equinoctial points along the ecliptic, called the precession of the equinoxes.

145. If on any day the moon is in conjunction with a fixed star, she will, after the above period of 27 days, 7 hours, 43 min., 11·461 sec., be in conjunction with it again; but between one conjunction with the sun and the next there are 29 days, 12 hours, 44 min., 2·87 sec., the period of her synodic revolution.

146. The difference between a sidereal and a synodic month may be explained in the same manner as the difference between a sidereal and a solar day. Let *S* (Plate III., Fig. I.) represent the sun, *E* the earth, and *M* the moon, in conjunction with the sun, and also with some fixed star. After a period of 27 days, 7 hours, 43 min., 11·461 sec., she will again be at *M'* in conjunction with the same star, and if the earth stood still she would be in conjunction with the sun also; but during that time the earth has been proceeding in her orbit, and has arrived at *A'*; and though the moon has revolved quite round the earth, she is not again in conjunction with the sun, but must continue her course 2 days, 5 hours, 0 min., 51·409 sec. longer, (the difference between a sidereal and a synodic revolution,) or until she arrives at *M"*, when she will again be in conjunction with the sun.

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* The centre of the earth is not, strictly speaking, the point round which the moon revolves, but both bodies revolve about their common centre of gravity. This point is situated at an average distance of 2690 miles from the centre of the earth, and is subject to a variation of rather more than 165 miles, in consequence of the variable distance between the earth and the moon.

147. Since the moon always presents the same side to the earth, the other side has alternately about a fortnight of sunlight and the same period of darkness; but the side which is constantly turned towards the earth will, during the time it is deprived of the direct light of the sun, enjoy a considerable quantity of reflected light from the earth's surface, as shown in Plate IV.

148. It is a remarkable fact, that one of the mountains situated on this side, and near the north pole of the moon, is so high, that although its base is enveloped in darkness during the fortnight it is turned from the sun, yet the top enjoys uninterrupted sunlight.

149. As the plane of the moon's orbit forms an angle of only about 5° 8½′ with the plane of the earth's orbit, she never departs much more than that distance from the ecliptic, either to the north or south of it; and if the course of the moon amongst the fixed stars be observed from night to night, the situation of the ecliptic, or the apparent path of the sun amongst the fixed stars, may be ascertained with tolerable accuracy.

PHASES OF THE MOON.

150. As the moon revolves round the earth she presents different phases, according to her situation with respect to the sun and the earth.

151. If observed early in the morning, a few days before the change, the crescent of the moon will be seen to the *west* of the rising sun, but evidently approaching him, as at *h*, (Plate III., Fig. III.); the next morning she will be about 13° nearer, and thus she advances until her change, when she is between the earth and the sun, as at *A*. Her dark side is now turned towards the earth, and she is invisible, as represented at *a;* proceeding in her orbit round the earth to *B*, a part of her enlightened side is brought into view, and she again makes her appearance in the evening sky about 30° to the *east* of the setting sun, as represented at *b;* when she has arrived at *C*, her first quarter, one-half of her enlightened disc is turned towards the earth, as shown at *c;* at *D* a greater part of her enlightened side is turned towards us, and she is then said to be gibbous, as represented at *d;* when arrived at *E*, the whole of her enlightened side is turned towards the earth, she is then in opposition to the sun, and appears full as at *e*. Continuing her course to *F*, she again appears gibbous, as at *f*, and gradually presents

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[illegible]

[illegible]

167. When the moon enters the earth's penumbra at *a*, (Plate IV., Fig. I.,) she loses a *portion* of the sun's rays, and, as she passes on, receives less and less light, until she is entirely enveloped in the umbra; at which time no *direct rays* can be received from the sun, and she is totally eclipsed, as at *M'*.

168. At this period of the eclipse, however, the whole disc of the moon is visible, shining with a very dull red light. This is caused by the refractive power of the earth's atmosphere, which acts as a lense, in refracting or bending some of the rays of light from the sun into the dark shadow of the earth, and concentrating them on the surface of the moon, thereby rendering her visible when totally enveloped in the earth's umbra. Proceeding in her orbit, she gradually emerges from the umbra, and receives more and more light from the sun, until she passes entirely out of the penumbra, at *a'*, and again receives his full light.

169. If the plane of the moon's orbit coincided with the plane of the ecliptic, there would be an eclipse of the sun at every new moon, and an eclipse of the moon at every full moon; but the plane of the lunar orbit is inclined to that of the ecliptic at an angle of about 5° 8½', subject to a variation of nearly 23' one way and the other. The latest tables of the moon give the greatest inclination 5° 20' 6", and the least 4° 57' 22".

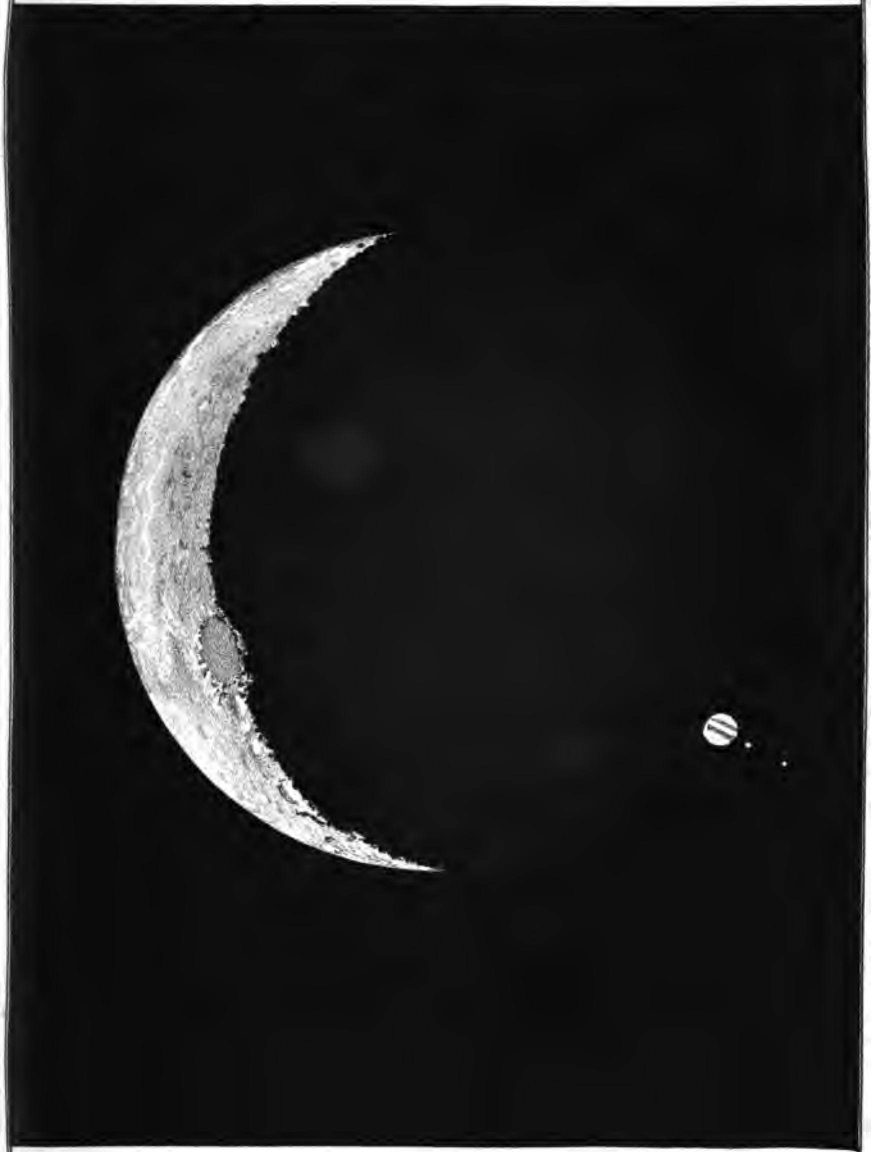
170. The two opposite points, where the plane of the moon, or of any other planet, intersects the plane of the ecliptic, are called the nodes. The ascending node is that, after passing which, the moon proceeds north of the ecliptic, or ascends above it; the descending node is that, after passing which, she descends below, or is south of the ecliptic. When either of these points is in a right line, or nearly so, with the centre of the earth and the centre of the sun, at either new or full moon there is an eclipse; if the moon is new, an eclipse of the sun, if full, an eclipse of the moon.

ECLIPTIC LIMITS.

171. According to the latest calculations, when the moon is more than 18° 36' from the true place of either the ascending or descending node at the time of conjunction, or new moon, she is either too high or too low to cast any part of her shadow upon the earth, and, consequently, there cannot be an eclipse of the

PLATE D.

The dark part of **THE MOON** rendered visible
by the Sun's light reflected from the Earth



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approaching an Occultation by the Moon.

See Article 147.

less and less of her enlightened side to the earth, as represented at *g* and *h*, until she again arrives at her conjunction and disappears.

152. The horns of the moon are always turned *from* the sun; therefore, from conjunction to the first quarter they point towards the east, and from the last quarter to the change they are turned towards the west. In the telescopic appearances of the moon, as given in Plates *A*, *C*, and *D*, the figure of the moon is *inverted.*

153. When the moon is either in conjunction as at *A*, (Plate III., Fig. III.,) or in opposition as at *E*, she is said to be in her *syzygy;* when half-way between these points, as at *C* or *G*, in her *quadrature.*

The Moon's Orbit round the Earth.

154. The moon's orbit round the earth is elliptical; and the earth being in one of the foci, the moon reaches her greatest, and also her least distance from the earth in each revolution. When the moon is at her greatest distance from the earth, she is said to be in *apogee;* when at her least distance, in *perigee:* and the line joining these two points, and passing through the centre of the earth, is called the line of Apsides.

155. The path of the moon is in every part concave towards the sun, but the diagrams usually employed to represent the phases of the moon and her path round the sun are generally on so small a scale that the proper proportions cannot be conveniently represented; consequently, the concavity of her path is not apparent, and the idea of a serpentine, and when passing her conjunction with the sun, of even a retrograde course is frequently conveyed. The concavity of her path, however, may be clearly shown by a diagram of moderate size, as it is not necessary to represent her path during an entire revolution round the sun; her course for one month will be sufficient. To represent this with tolerable accuracy, take a radius of 95 inches (95 millions of miles the distance of the earth from the sun) and describe, by the help of a piece of string fastened on the floor of the room, or on a long table, the arc *A B*, (Plate III, Fig. IV,) 4¼ feet in length, to represent a portion of the earth's orbit round the sun, over which she travels in about a month. Divide this arc into four equal parts, and make a dot about as large as a pin's head at each point; these dots will represent the situation of the earth at the end of each week. Again, with a radius of a quarter of an inch (a quarter of a million of miles) describe a circle round each dot, to represent the orbit of the moon round the earth. Make a very small dot at *a*, to represent the moon

at full, another at *b*, for her third quarter, one at *c*, to represent her place at her change, another at *d*, for her place at her first quarter, and another at *e*, which will represent her place when again at full. Draw a line from *a*, through *b*, *c*, *d*, and *e*.. This line will represent the moon's path during one revolution round the earth, and will be concave towards the sun in every part, and, with tolerable accuracy, will represent a portion of the moon's path round the sun. It will be evident, from the figure, that the versed sine, *m n*, of the arc *b*, *d*, is greater than the radius of the moon's orbit round the earth, and proves the concavity of the moon's path round the sun. If this versed sine were less than the radius of the moon's orbit round the earth, that portion of the moon's path from *b*, to *d*, would be convex towards the sun.

156. Whilst the moon is proceeding from her first quarter to her last, her progressive motion in her path round the sun is accelerated, by her orbitual motion round the earth, and is greater than that of the earth; but whilst proceeding from her last quarter to her first, her progress is, from the same cause, retarded, and is slower than that of the earth.

ECLIPSES.

157. Though eclipses are amongst the most popular of the celestial phenomena, yet they are not of so much importance at the present day as many of those which are less observed.

Solar Eclipses.

158. A *solar eclipse* is caused by the moon passing between the earth and the sun, when the shadow of the moon falls on the earth. This can only happen when the moon is in conjunction, that is, at the time of *new moon*, and then the moon must be in or near one of her nodes.

159. Let *S* (Plate IV , Fig. I.) represent the sun, *M*, the moon at the time of conjunction, and *E*, the earth, *m*, *n*, *o*, the umbra, or dark shadow of the moon, and the light shade, the penumbra. There will be a total eclipse of the sun to that part of the earth's surface where the umbra falls, but a partial eclipse at those parts within the penumbra.

160. Eclipses of the sun vary in magnitude according to the distance of the moon from the earth, and of both from the sun. When the moon in perigee eclipses the sun, she appears large enough to cover his entire disc from that part of the earth on which her shadow falls, and a total eclipse then takes place.

161. If the moon be in apogee when she eclipses the sun, she is so far from the earth that her diameter subtends a *less* angle than the sun's, and her conical shadow does not touch the earth: but at the place to which the point of the shadow is directed, the whole of the centre of the sun will be eclipsed, whilst the edge will appear like a luminous ring round the dark body of the moon; hence it is called an *annular* eclipse, but is of rare occurrence.

162. The extent of an eclipse of the sun is affected by the geographical position of the spectator; for if the eclipse be *total*, the shadow of the moon cannot, under any circumstances, cover a portion of the earth's surface more than 180 miles in diameter; but the penumbra, within which the eclipse is *partial*, extends, at the same time, over an area of about 4,900 miles in diameter.

163. *Illustration;* (Plate IV., Fig II.)—Suppose the sun to be vertically eclipsed at the equator; the moon's umbra, enveloping in total darkness that part of the earth where it fell, would cause a total eclipse; whilst, to a person at *c*, south of the equator, but within the limits of the penumbra, the eclipse would be partial, the *northern* limb of the sun only being eclipsed, as shown by the direction of the line *c, c'* ; and, to a spectator at *d*, near the limit of the penumbra, only a very small portion of the *southern* limb would be eclipsed, as at *d'* ; whilst, to a spectator at *e* or *f*, there would not be an eclipse.

164. The occultations of the planets and fixed stars by the moon are also similarly affected by the geographical position of the spectator. For example, a person at *a* (Plate I., Fig. IV.) would witness an occultation of a planet at *m''*; whilst, another at *L*, would at the same time see the planet some minutes of a degree above the northern limb of the moon.

165. A total eclipse of the sun does not occur very frequently, and seldom continues longer than three minutes in one place. Under the most favourable circumstances, or when the earth is at her *greatest* distance from the sun, and the moon at her *least* distance from the earth, the apparent diameter of the moon exceeds the apparent diameter of the sun only two minutes of a degree: consequently a total eclipse of the sun can continue at one place, no longer than whilst the moon is passing two minutes of a degree in her orbit, or about 3 min. 38 sec. of time.

Lunar Eclipses.

166. An eclipse of the moon is caused by her entering the shadow of the earth, and can only happen when the moon is in opposition to the sun; that is, at the time of full moon.

167. When the moon enters the earth's penumbra at *a*, (Plate IV., Fig. I.,) she loses a *portion* of the sun's rays, and, as she passes on, receives less and less light, until she is entirely enveloped in the umbra; at which time no *direct rays* can be received from the sun, and she is totally eclipsed, as at *M'*.

168. At this period of the eclipse, however, the whole disc of the moon is visible, shining with a very dull red light. This is caused by the refractive power of the earth's atmosphere, which acts as a lense, in refracting or bending some of the rays of light from the sun into the dark shadow of the earth, and concentrating them on the surface of the moon, thereby rendering her visible when totally enveloped in the earth's umbra. Proceeding in her orbit, she gradually emerges from the umbra, and receives more and more light from the sun, until she passes entirely out of the penumbra, at *a'*, and again receives his full light.

169. If the plane of the moon's orbit coincided with the plane of the ecliptic, there would be an eclipse of the sun at every new moon, and an eclipse of the moon at every full moon; but the plane of the lunar orbit is inclined to that of the ecliptic at an angle of about 5° 8½', subject to a variation of nearly 23' one way and the other. The latest tables of the moon give the greatest inclination 5° 20' 6", and the least 4° 57' 22".

170. The two opposite points, where the plane of the moon, or of any other planet, intersects the plane of the ecliptic, are called the nodes. The ascending node is that, after passing which, the moon proceeds north of the ecliptic, or ascends above it; the descending node is that, after passing which, she descends below, or is south of the ecliptic. When either of these points is in a right line, or nearly so, with the centre of the earth and the centre of the sun, at either new or full moon there is an eclipse; if the moon is new, an eclipse of the sun, if full, an eclipse of the moon.

ECLIPTIC LIMITS.

171. According to the latest calculations, when the moon is more than 18° 36' from the true place of either the ascending or descending node at the time of conjunction, or new moon, she is either too high or too low to cast any part of her shadow upon the earth, and, consequently, there cannot be an eclipse of the

sun. If the moon's latitude exceed 1° 34′ 52″, an eclipse of the sun is ***impossible***, but if it be less than 1° 23′ 15″ an eclipse ***must*** take place. If the moon is more than 12° 24′ from the true place of either node at the time of opposition, or full moon, she will be either too high or too low to come in contact with any part of the earth's shadow, and therefore will pass her opposition without being eclipsed; or, if her latitude exceed 63′ 45″, she will not be eclipsed, but if it be less than 51′ 57″, an eclipse is certain.

172. Eclipses of the sun are more frequent than those of the moon, because the sun's ecliptic limits, *i. e.*, the distance from the nodes, (18° 36′,) within which an eclipse may occur, are greater than the moon's, (12° 24′,) yet there are more *visible* eclipses of the moon at any particular place, than of the sun, because, when the moon is eclipsed she actually loses her light, and therefore the eclipse, like the ordinary phases of the moon, is visible, and also appears of the same magnitude at all those parts of the earth where the moon is above the horizon; but eclipses of the sun are visible only to those parts of the earth where the shadow of the moon falls.

173. A right line drawn from one node to the other, through the earth's centre, is called the line of the nodes. If this line continued exactly parallel to itself, or, in other words, was always directed to the same point in the heavens, whilst being carried round the sun, the nodes and the sun would be in conjunction about every six months, and we should have eclipses then, and at no other time: but this is not the case; the nodes have a constant retrograde motion along the ecliptic, amounting, on an average, to very nearly 19½° in a year, and therefore the same node comes round to the sun about 19 days earlier every year than it did the preceding year; consequently, at whatever time of the year there are eclipses about either node, in $\left(\frac{365-19}{2}\right) = 173$ days afterwards there will be eclipses about the other node.

174. This retreat of the nodes along the ecliptic amounts to an entire revolution in 18 yrs., 218 days, 21 hours, 22 min., 46 sec., in which time there would always be a regular return of eclipses, if any complete number of lunations were finished without a fraction; this, however, never occurs; but in 223 mean lunations after the sun, moon, and nodes have been in conjunction, they will be within 28′ 12″ of a line of conjunction again: therefore at the end of this period there will be a return of the same eclipses. This is what is meant by the cycle of the moon's nodes, and is the celebrated Chaldean Saros. It consists of about 18 years, 10⅓ days, or 18 years, 11⅓ days, according as there are five or four leap years in the interval. If, therefore, to the mean time of any eclipse

this period be added, the mean time for the return of the eclipse is obtained; and it is supposed that the Chaldeans and other ancient nations used this period in predicting eclipses.

175. The least number of eclipses that can happen in a year is two, and if there be only two, they must be both of the sun. There may be seven, five of the sun, and two of the moon, though there are seldom more than six; but the usual number is four.

THE APPARENT MOTION OF THE SUN AMONGST THE FIXED STARS; THE SEASONS, &c.

176. The sun appears to perform an entire circuit of the heavens every year. This path is called the ecliptic (Art. 13,) and the sun's *apparent* motion amongst the fixed stars is caused by the *real* motion of the *earth* in her orbit.

177. The apparent motion of the sun and the various phenomena produced by it, may be very easily understood by means of a simple apparatus which may be readily procured. It consists of a small terrestrial globe, two or three inches in diameter, placed on a stick or wire, six or seven inches long, to represent the axis.

178. Should a small terrestrial globe not be easily procured, an apple, an orange, or a common wood ball will answer nearly as well, but either of the latter will require to have a few lines described on its surface. Thus, take any two points on the ball exactly opposite each other, to represent the north and south poles, and make a hole completely through to receive the axis; round the middle of the ball, and at an equal distance from each pole, draw a line to represent the equator. At 23½°, or about one quarter of the distance between the equator and the poles, draw two lines quite round the ball, parallel to the equator, to represent the tropics, and at the same distance, 23½°, from each pole, draw lines to represent the arctic and antarctic circles.

179. Place a table in the middle of the room, and on it a candle or lamp, the flame of which should be about six inches above the table, to represent the sun (Plate V., Fig. I.); draw a line, or suppose one to be drawn quite round the walls of the room, at the same height from the floor as the candle, this will represent the ecliptic. On this ecliptic line, at equal distances from each other, place small pieces of paper, to represent the twelve signs of the zodiac, placing the sign Cancer on the middle of the north wall of the room, facing which you are supposed to be standing; directly opposite to it, or behind you, place Capricornus; on the east wall,

to your right hand, place Aries; on the left, Libra; and the other signs in their proper order. The point in the ceiling exactly over the lamp will represent the pole of the ecliptic. The axis of the globe should be of such a length that the centre of the globe, when the axis is inclined at the proper angle, (23½°,) and resting on the table, may be of the same height as the centre of the light. This may be ascertained by observing when the shadow of the globe falls on the ecliptic. Hold the globe, by means of its axis, in such a position that it may be in a line with the sun and the sign Cancer, and at the distance of fourteen or fifteen inches from the former, then incline or bend the axis at an angle of 23½° from the perpendicular towards Cancer, and consequently towards the sun.

180. The north pole will now point to the north pole of the heavens, in which direction the axis of the earth must point during the entire revolution. The globe in this situation will represent the exact position of the earth on the 21st of June, or at the time of the summer solstice, and the sun will appear, as seen from the earth, to be entering the sign Cancer. If by any means, the globe can be fixed for a short time in this position, so as to allow of a leisure and careful examination, it will be seen that the sun is then vertical over the tropic of Cancer; that his rays, which always enlighten one half of the globe at one time, shine 23½° over the north pole, causing constant day to all parts within the arctic circle, and fall 23½° short of the south pole, producing constant night to all parts within the antarctic circle. At the equator, just twelve meridians, each 15° apart, will be in the light, and the same number in darkness. In the latitude of London, more than sixteen will be in the enlightened hemisphere, and not quite eight in the dark, agreeing with the length of our longest day and shortest night; whilst, in the same latitude, south, there will be not quite eight meridians enlightened, showing the length of the shortest day there.

181. If the globe is now caused to rotate from west to east, by the south,* the parts within the arctic circle will be seen to enjoy continual sunlight, whilst those within the antarctic circle will have perpetual night; but to all other parts of the earth the sun will rise and set.

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* The sun and all the planets and their satellites, whose rotation has been ascertained, rotate on their axes from west to east. The planets, also, revolve round the sun, and the satellites round their primaries (those of Uranus alone excepted) in the same way.

182. Carry the earth forward in her orbit from left to right, preserving the parallelism of the axis, which must always incline towards the beginning of Cancer, and the sun will appear to move amongst the fixed stars, in Cancer towards Leo. When the earth has proceeded over one twelfth of her orbit, the sun will appear to be entering the sign Leo, and, as the north pole of the earth is not now turned *directly* towards the sun, his rays will not extend beyond the pole quite so far as the arctic circle. As the earth proceeds in her orbit, the sun will enter Virgo; the number of degrees he shines over the north pole is now greatly diminished, and his rays will be seen to advance towards the south pole. When the earth has accomplished one fourth part of her orbit, the sun will appear to be entering Libra, and, being now vertical over the equator, will shine from pole to pole. In all latitudes there will be twelve meridians in the light, and the same number in darkness; the days and nights being equal all over the world. This represents the position of the earth on the 23rd of September, the time of the autumnal equinox. As the earth advances in her orbit, the north pole becomes a little turned from the sun, consequently his rays do not reach quite to it, whilst the south pole, being now directed towards the sun, enjoys constant day. When the earth has advanced over one-half of her orbit, the sun is seen to enter Capricornus, and is vertical over that tropic, causing summer in the southern hemisphere. The north pole is now turned directly *from* the sun, the whole of the north frigid zone is in perpetual darkness, whilst the south frigid zone, in its turn, enjoys uninterrupted sunlight. This position of the globe represents the earth at the time of the winter solstice, the 21st of December. In the latitude of London, only about eight meridians are now in the light, but in the same latitude, south, the day is at its greatest length, and more than sixteen meridians are in the sunlight. As the earth advances, the sun appears to move from Capricornus, through Aquarius and Pisces, towards Aries; which sign he enters on the 21st of March, the time of the vernal equinox.

183. Whilst the earth is proceeding in this latter part of her orbit, the north pole is gradually turned less from the sun, and when the sun enters Aries, he is again vertical over the equator, and shining from pole to pole, produces equal day and night over the whole earth. Advancing in her orbit, more of the arctic regions becomes enlightened, and the rays of the sun gradually leave the antarctic regions, until the earth has arrived at that part of her orbit where the sun is again seen entering the sign Cancer, and, darting his direct rays over the tropic bearing that name, gives perpetual day to the whole of the north frigid zone.

PRECESSION OF THE EQUINOXES.

184. The precession of the equinoxes, or the retreat of the equinoctial points along the ecliptic, has been referred to, (Art. 110,) and may be readily understood by the aid of the apparatus just described. Suppose yourself standing at the table in the same position as before, with the earth, sun, and Cancer in a right line before you. Hold the axis of the globe perpendicular to the table, and consequently, perpendicular to the plane of the earth's orbit. In this position, suppose the plane of the earth's equator to be extended on all sides to the walls of the room, and the equinoctial to be again drawn, it will be found to coincide with the ecliptic previously marked, (Art. 179.) But this is not the case in nature, the equinoctial cuts the ecliptic at an angle of about 23½°. To represent this, incline the axis of the earth 23½° as before, towards the beginning of Cancer, and again, suppose the plane of the equator to be extended on all sides and traced on the wall. It will be seen that the part of the equinoctial in the direction of the sign Cancer, and which previously coincided with the ecliptic there, is now, in consequence of the inclination of the axis, brought 23½° below it, whilst the part on the wall behind, or towards Capricornus, is elevated the same number of degrees above it; therefore, since one part of the equinoctial is above the ecliptic and the opposite part below, it follows that the equinoctial must cut the ecliptic in two opposite points; these, it will be seen, are the beginnings of the signs Aries and Libra, and are called the equinoctial points, because when the sun is in either of them the days and nights are equal all over the world. A great circle passing through these points and the celestial poles is called the *equinoctial colure.* The *solstitial colure* is a great circle at right angles to the equinoctial colure, and passes through the beginnings of the signs Cancer and Capricorn. The points of intersection of these circles with the ecliptic are continually changing, owing to the precession of the equinoxes. About 2000 years ago, when the stars were first grouped into constellations, the equinoctial colure nearly coincided with the two principal stars in Aries; but the point of intersection, which is still called the beginning of Aries, is removed about 30° to the west of this constellation, the place it now occupies on our modern celestial globes.

185. The axis of the earth is generally said to point always in the *same* direction, but this is not strictly true*;* were it so, the equinoctial would always intersect the ecliptic exactly in the same

places; but the points of intersection are found to have a constant westward, or retrograde motion along the ecliptic, amounting to very nearly 50¼ seconds of a degree every year. Suppose, that during a number of revolutions of the earth round the sun, you gradually direct the axis of the earth to a point in the ceiling of the room a little to the right of that to which it pointed when the previous intersection was made, or until it inclines towards the beginning of Gemini, instead of the beginning of Cancer, and again trace the equinoctial on the walls; it will be seen that the points of intersection will not be in the same places in the ecliptic as before, but removed to the right of their former positions. This change in the direction of the axis of the earth is constantly, though gradually going on, and the consequent shifting of the points of intersection along the ecliptic is what is meant by the *precession of the equinoxes.* It is so called, because the equinoctial points, though retreating along the ecliptic, meet the sun in that circle a little earlier every year, thus making the tropical year rather shorter than the sidereal (Art. 110); for should the centre of the sun be exactly in a line with a fixed star in any year when it crossed the equinoctial, the next year the point of intersection would be a little to the west of the same star.

186. The precession of the equinoxes is caused by the attractive influence of the sun and moon upon the exuberant matter about the equatorial regions of the earth.

187. The amount of precession, as before stated, is nearly 50¼ seconds every year, therefore, in about 72 years from the present time, the equinoctial will cut the ecliptic one degree to the west of the points where it now intersects it, consequently the north pole of the heavens will be moved from the place it now occupies, and will be brought nearer the pole star, which it will continue to approach until it is within about half a degree of it. Afterwards the pole will gradually leave it, and for many centuries no star of importance will mark the position of the pole in the heavens, but this same slow change in the direction of the axis continued for about 13,000 years from the present time, would cause it to be directed to a point in the heavens within about 5° of the bright star Vega, (α Lyræ,) and, in rather more than 25,800 years, the pole of the equinoctial would make an entire revolution round the pole of the ecliptic. This period is called the Platonic year.

THE TIDES.

188. The alternate ebbings and flowings of the sea, denominated *the tides*, are caused by the attraction of the sun and moon, but especially by that of the latter, in consequence of her greater proximity to the earth; for, although the moon is so powerfully attracted by the earth as to be retained in her orbit, yet she, at the same time, exerts an attractive influence over the earth which is so strikingly perceptible in the effect it has on the waters of the ocean.

189. By the law of attraction those parts of the earth nearest the moon are more powerfully attracted than the central parts, and the central parts more powerfully than the parts on the opposite side of the earth. In consequence of these different degrees of attraction being exerted on different parts of the earth, that diameter of the earth which is directed towards the moon is lengthened, and the waters about the two extremities form the tides. Therefore, it is not simply the attraction of either the sun or moon, but the *inequalities* in that attraction, which produce the tides.

190. Since one portion of the solid mass of the earth cannot be moved without moving the whole, that part of the earth most distant from the moon, is by its connexion with those parts nearest the moon, as much affected as they are, and is drawn from the more distant waters, which are thus left behind. A tide is therefore produced on opposite sides of the earth at the same time, and by the same agency.

191. Another cause of the tides arises from the motion of the earth round the common centre of gravity of the earth and moon. (See Plate V., Fig. II., also note, page 35.) The centre of the earth has its centripetal and centrifugal forces so balanced as to retain it in its orbit round *C*, the common centre of gravity of the earth and moon. That part of the earth, therefore, nearest to the moon, in consequence of its describing, in the same time, a smaller circle (*d e f g*) than the centre of the earth does round this common centre of gravity, has *less* centrifugal force than the centre; whilst that part of the earth most distant from the moon, describing a larger circle (*m n o p*) in the same time, has *greater* centrifugal force than the centre; consequently, that diameter of the earth, which if continued would pass through the moon, is lengthened, and the waters about the extremities form what are termed *centrifugal* tides.

192. Since the earth rotates on her axis from west to east, the course of the great tidal wave, where uninterrupted by land, is from east to west, and where it does not meet with any obstruction, as in the great Pacific, it does not generally rise many feet, neither does the water form a current, but is merely elevated as it is brought under the influence of the moon, and when that influence ceases, it subsides in the same place; but when this elevation approaches shores where the sea is comparatively shallow, or when driven up narrow channels or estuaries, it produces a current, and sometimes rises to a great height, as is the case on several parts of our own coast, especially in the Bristol Channel.

193. We have hitherto considered the agency of the moon only in producing the tides, but the sun also exerts an influence, sometimes in conjunction with her, but as often in opposition.

194. The sun attracts the earth much more powerfully than the moon does, but in consequence of his great distance, this attraction is more uniform, being nearly the same on all parts of the earth, consequently it tends but little to change her figure, yet when it acts in conjunction with the attraction of the moon at the time of the change or new moon, as at *m*, (Plate V., Fig. III.,) their influences are united to raise the water in those parts which are turned towards them, and produce what are technically called *spring tides;* and also, when the moon is in opposition, as at *m'*, a similar effect is produced; but when the moon is in quadrature, as at *m*, (Plate V., Fig. IV.,) and is drawing the waters in the direction *E m*, the sun is also acting upon them in the direction *E S*, and by retaining them at *D*, in some measure counteracts the effects of the moon on the waters at *m'*, and causes what are called *neap tides*.

MARS.

195. *Mars* is the first of the superior planets (so called because their orbits lie outside the orbit of the earth,) and is distinguished from the fixed stars by the red fiery colour of his light, which by some astronomers is supposed to arise from the density of his atmosphere, and by others from the natural colour of the surface of the planet.

196. Mars is much smaller than the earth, his diameter being only about 4,500 miles. He rotates on his axis in 24 hrs., 37 min., 20 sec., and revolves round the sun in 686 days, 23 hrs., 30 min., 41 sec., at the mean distance of 145,205,000 miles.

197. The plane of the orbit of Mars nearly coincides with that of the earth, making an angle with it of only about 1° 51′ 3″, consequently he is never seen far from the ecliptic either to the north or south. The axis of Mars makes an angle of 28° 42′ with a perpendicular to the plane of his orbit, and from this inclination his seasons are very similar to those of the earth, to which, in other respects, he is also thought to bear a strong resemblance.

198. Mars also exhibits phases similar to those of the moon, a few days before, and after the full. When viewed through a powerful telescope, the surface of Mars appears varied, and, about the poles, bright white portions are observed, which partially disappear after the pole has been turned for some time towards the sun. This circumstance has given rise to the supposition, that these parts are covered with snow during the polar winter of Mars, similar to the arctic regions of our earth, but which melts during the summer months.

DIRECT AND RETROGRADE MOTIONS OF THE SUPERIOR PLANETS.

199. As the orbits of the superior planets lie beyond the orbit of the earth, they are seen in all parts of the heavens; sometimes in conjunction with the sun, but as often in opposition. Their motions appear to be retrograde (or contrary to the order of the signs) from their stationary point before opposition, to their stationary point after opposition, and direct from their stationary point before conjunction to their stationary point after conjunction.

200. The apparent retrograde motion of the superior planets arises from the earth moving more rapidly in her orbit than they do in theirs. These appearances could not be produced if the earth were at rest, and afford a convincing proof of the annual motion of our globe round the sun.

201. *Illustration.*—Let *S*, represent the sun, (Plate VI., Fig. I.,) *E*, the earth in her orbit, and *M*, Mars, approaching opposition; also *A*, *B*, an arc of the heavens. When the earth is at *E*, and Mars at *M*, he will be seen amongst the fixed stars at *m*, will for a short time appear stationary, and from this point his retrograde motion commences. But since an inferior planet moves with greater velocity in its course than a superior planet, suppose the earth to move from *E*, to *E'*, whilst Mars moves from *M* to *M'*, (his stationary point after opposition,) he will then appear to have *retrograded* through the arc *m*, *m'*, and, at some intermediate point between *m* and *m'*, will have been in *opposition* to the sun; after this his *direct* motion commences. Again, suppose the earth to be at *e*, and Mars at *M*, approaching his conjunction with the sun, he will appear in the heavens at *n*, and, proceeding in his orbit, from *M* to *M'*, whilst the earth moves from *e* to *e'*, his motion will be *direct*, and will continue so until he again reaches his stationary point before opposition. At some intermediate point between *M* and *M'*, he will have been in *conjunction* with the sun.

202. The retrograde motion of the superior planets may be familiarly illustrated in the following manner. Suppose a person in the cabin of a ship under sail, but unconscious of his progressive motion, fixes his attention on a boat proceeding from *A*, towards *B*, (Plate VI., Fig. II.,) and at that time in a line with an object *(n)* on the opposite shore. If the ship sails from *P* to *p*, in the same time that the boat goes from *A* to *a*, the boat has, during this time, appeared to be receding from *n*, and is now in a line with another object on the shore at *n'*. The boat having advanced to *a'*, whilst the ship has sailed to *p'*, it appears at *n''*, and, from the ship at *p''*, the boat at *a''*, appears at *n'''*. Thus, although the boat has in reality been moving forward, its motion has appeared, in relation to objects on the shore, to be backward, or retrograde. Thus the retrograde motions of the planets are only instances of relative motion on a large scale, and are in perfect accordance with the Copernican system

THE ASTEROIDS, OR ULTRA-ZODIACAL PLANETS.

203. The disproportionate space between the orbits of Mars and Jupiter, led astronomers to think it probable that some planet or planets might exist there, and these conjectures were confirmed between the years 1800 and 1807 by the discovery of four very small planets, named Vesta, Ceres, Juno, and Pallas, and since that time many other similar planets have been discovered, moving in orbits nearly at the same distance from the sun, and performing their revolutions in periods of from 1193 to 2044 days. Their diameters have not yet been accurately determined.

204. Various are the conjectures respecting the origin of these diminutive planets. Some astronomers suppose them to be the remains

of some large planet that had formerly revolved in nearly the same part of the heavens which they now occupy, but which had been shattered by some convulsion, and that the fragments, retaining the motion of the original planet, continue to revolve round the sun in nearly the same circuit.

JUPITER.

205. This is the largest of all the planets, his diameter being upwards of 88,780 miles, and his mean distance from the sun 495,817,000 miles.

206. He rotates on his axis in rather more than 9 hrs., 55 min., and, in consequence of this rapid rotatory motion, his equatorial diameter exceeds his polar diameter by nearly 7000 miles. The extreme flattening about the poles of Jupiter may be distinctly seen by a good telescope.

207. He is surrounded by a number of zones, or belts, chiefly about his equatorial parts, and generally parallel to his equator. They are liable to considerable changes in their breadth and number, and have sometimes been known to be broken into fragments and again to resume their usual appearance. From these circumstances they are supposed to be produced by clouds or currents in his atmosphere, similar to our trade winds, and this supposition is strengthened when we consider the great rapidity with which Jupiter revolves on his axis, his equatorial parts being carried at the enormous rate of 27,000 miles per hour.

208. Jupiter completes his revolution round the sun in 11 yrs. 314 days, and as his axis makes an angle of only 3° 4′ 5″ with a perpendicular to the plane of his orbit, he can have no variety of seasons, and but very little difference in the lengths of his days and nights. The sun is always nearly vertical over his equator, the width of his torrid zone being only 6° 8′ 10″, and, at the poles, the sun never attains an altitude of more than 3° 4′ 5″ above the horizon. The days and nights throughout the year, and on all parts of the surface, are nearly equal, each being about 4 hrs., 57½ min. in length.

The Satellites of Jupiter.

209. Jupiter is attended by four satellites, or moons, which revolve around him in strict accordance with those general laws which pervade the whole planetary system, and especially with that which connects the periods of the revolutions of the planets with their distances.

223. Uranus revolves round the sun, according to Le Verrier, in rather more than 84 of our years, at the mean distance of 1,828,071,000 miles, but the period of rotation on his axis has not been satisfactorily ascertained. His diameter is nearly 35,000 miles, and he is supposed to be attended by six satellites; but the periods and distances of only four have been ascertained with tolerable accuracy. They move in orbits nearly perpendicular to the plane of the orbit of their primary, and with this striking peculiarity, that, contrary to the otherwise unbroken law that pervades the whole planetary system, they revolve in their orbits from east to west.

NEPTUNE.

224. The discovery of this planet has been justly considered one of the greatest achievements of mathematical science. Its existence was simultaneously inferred by Adams and Le Verrier, from some irregularities which were noticed in the motion of Uranus. This planet had been previously seen by astronomers, but was then supposed to be a fixed star.

225. The diameter of Neptune is stated to be about 31,000 miles, and the period of revolution round the sun about 164½ of our years, at the mean distance of 2,862,457,000 miles. One satellite has been discovered, and it is supposed that others exist.

COMETS.

226. The appearance of a comet has, in all ages, been regarded as something extraordinary, and though they are not now viewed with superstitious terror, as the harbingers of Divine vengeance, yet their nature remains enveloped in mystery. Many of them, undoubtedly, belong to the solar system, and these move round the sun in elliptical orbits, though exceedingly elongated, and are subject to the same laws that govern the planetary system. The orbits of several have been calculated, and their returns predicted with great accuracy. Others however, are supposed to visit our system but once, and then, flying off into the immeasurable

regions of space, continue their course until they come within the influence of some fixed star, around which they are whirled, as they previously were around our own sun, and are again thrown off into space to visit other more distant stars. These move in hyperbolical curves, whose property it is never to return into themselves, but, their extremities continually diverging, to run out into infinity.

227. Comets consist of a nebulous mass of light, called the head, in the centre of which there is generally a bright point, called the nucleus. Two streams of light diverge from the head, in an opposite direction to the sun, but soon unite and form what is called the tail, which is sometimes of an immense apparent length. Passing by the accounts of several which are are left on record by the ancients, most of which are undoubtedly exaggerated, the tail of the comet of 1680 is said to have extended over a space of more than 70° of the heavens. Many of the larger comets, however, have short tails, and several appear to be quite destitute of this appendage.

CHAPTER III.

THE FIXED STARS.

228. Leaving the confines of our solar system, and proceeding to explore the depths of infinite space, we find that each shining point which sparkles in our nocturnal sky, is a sun, vast and brilliant as our own, and owes its diminished appearance only to its immense distance from us.

229. By the most recent observations, the distance of α Centauri, is found to be nearly twenty millions of millions of miles from us, or so remote, that light, which travels at the rate of 192,000 miles in one second of time, would be about 3¼ years in coming from this star to the earth. The distance of 61 Cygni, the parallax of which has been satisfactorily obtained, is, according to Bessel, about three times the distance of α Centauri. Yet these stars, in comparison with others yet more remote, are in the immediate vicinity of our solar system.

230. At present we have no means of obtaining any accurate knowledge of the size of the stars, for though we judge from their brilliancy, in connexion with their distance, that some of them, at least, must far exceed our own sun in magnitude, yet, when a fixed star is viewed through the most powerful telescope it appears a mere shining point, and presents no measurable disc.

231. The colour of their light also varies. Some are red, amongst which are Arcturus and Aldebaran. Sirius and Vega shine with a white light. The Pole star, with some others, is yellow, and Castor appears of a greenish hue.

232. The stars were grouped together in constellations by the ancient astronomers, and the same figures which they assigned to them are still retained for the convenience of reference. They are also divided into sixteen classes, according to their brightness, or

apparent magnitudes. The most brilliant, to the number of fifteen or twenty, are called stars of the first magnitude, though thirteen only are mentioned in the Nautical Almanac. The second class comprises stars of the second magnitudes, to the number of fifty or sixty, and so on, to the third, fourth, &c., magnitudes. Stars fainter than those of the fifth magnitude can seldom be seen by the naked eye, except under very favourable circumstances. The remaining classes are called telescopic stars.

233. A very remarkable feature in some of the fixed stars is their periodical change of brilliancy. Amongst the most remarkable of these are Mira in Cetus, and Algol in Perseus. The former appears once in eleven months, remains at its greatest brightness about a fortnight, and then decreases for about three months, until it becomes invisible to the naked eye. It remains so about five months when it again becomes visible. Algol in Perseus varies from the second magnitude to the fourth in 3½ hours, and in 3½ more regains the splendour of the second magnitude, which it retains for two days and fourteen hours, after which it again decreases, and repeats the same changes with great regularity. These, with several others of a similar kind, are called *variable stars*. The cause of their variation in brilliancy is unknown, but it is supposed to arise either from the periodical obstruction of some opaque body revolving round the star, or by some less brilliant portions of its surface being presented to our view by its rotation on its axis.

234. Several stars marked in the old catalogues are now missing, whilst others, at different periods, have appeared, and after continuing for a time have entirely disappeared.

235. Several stars which appear single to the unassisted eye, are, when viewed through a telescope, found to be double, treble, &c., and in several instances, the stars composing these systems have a revolution round each other. The most considerable double stars are, Rigel in Orion, the Pole Star, Cor Caroli, and Vega; which, with the exception of Vega, are easily resolved. The small star ε of Lyra, very near Vega, under a low power appears a double star, but when examined by a higher power, each star of the couple is also found to be a double star.

236. The "*fixed stars*" do not absolutely retain the same position in relation to each other, but this relative change, which is called their *proper motion*, is so slight that it can only be detected by the most careful and continued instrumental observation.

237. In consequence of this relative change of situation being most apparent amongst the stars in and about the constellation Hercules, which are becoming gradually more separated, whilst

the stars in the opposite part of the heavens are approaching each other, it is supposed, as stated in Art. 60, that our sun, with the whole solar system, is advancing towards that constellation; and, reasoning from analogy, astronomers also suppose that the whole of our firmament of stars is moving round some fixed point in space, and all the observations that have been made relative to this subject tend to confirm their belief in this opinion.

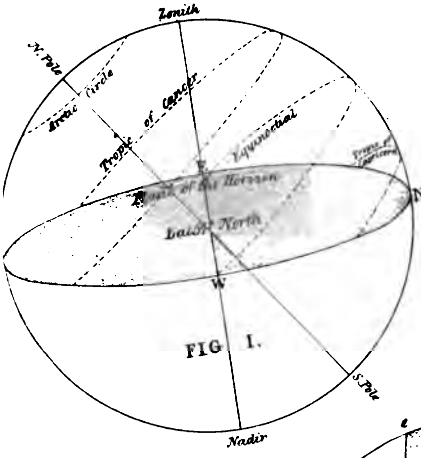
NEBULÆ.

238. Looking through, or beyond our own firmament of stars, we see, scattered in different parts of the heavens, detached portions of whitish light, denominated *Nebulæ*, some of which are visible to the unassisted eye, but when viewed through a telescope they are found to be firmaments of stars similar to our own, but so infinitely distant from it that the rays of light are so blended that only instruments of the highest power are able to resolve them. The powerful telescope constructed by Lord Rosse has succeeded in throwing much light on nebular phenomena, but some of the nebulæ are so distant as to escape the space-penetrating power of even this magnificent instrument.

FINIS.

J. COULTAS, PRINTER, YORK.

PLATE I.



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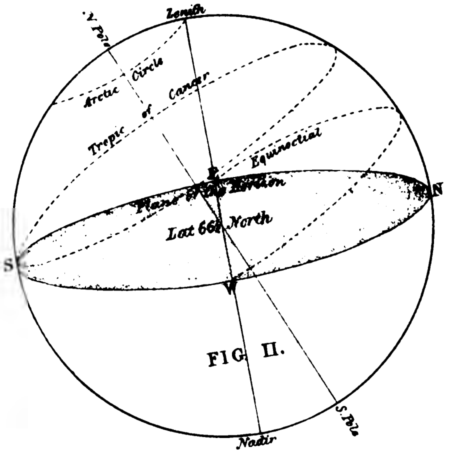

FIG. II.

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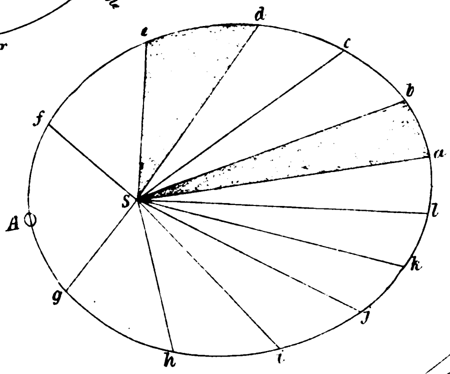

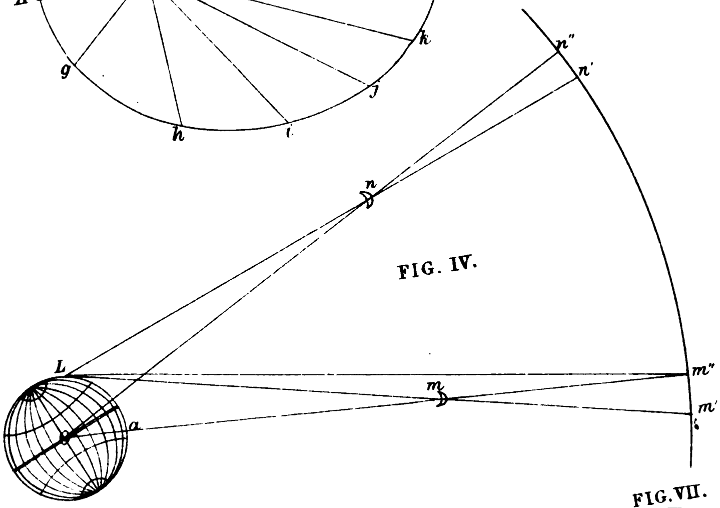

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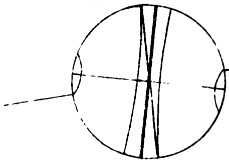

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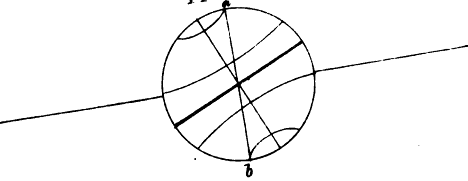

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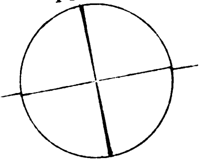
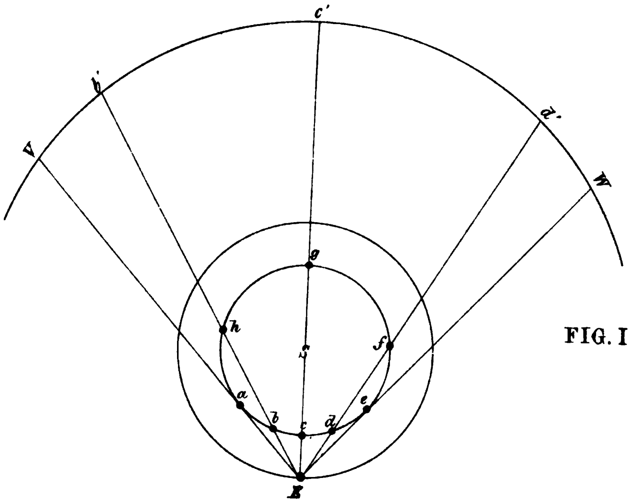


W. Monkhouse, Lith.

PLATE. II.



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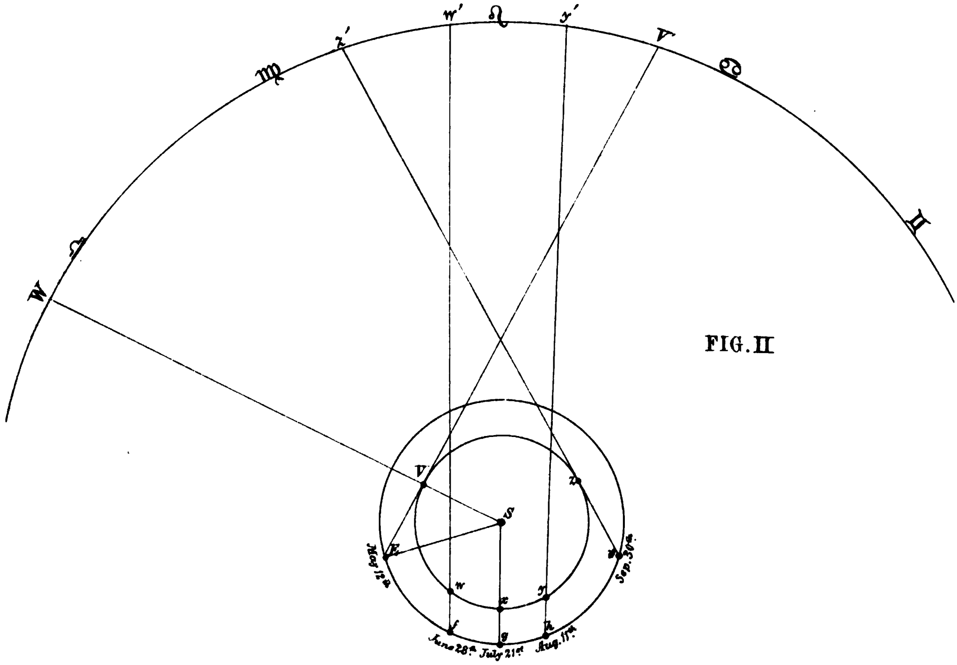
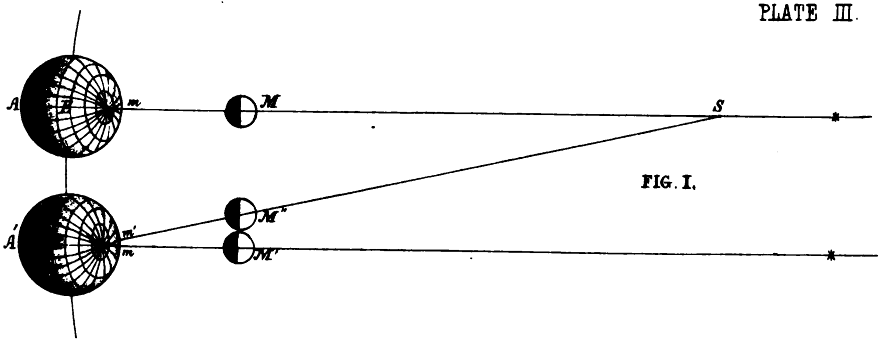


FIG. II

Venus passing her Inferior Conjunction with the Sun 1852.

W Monkhouse, Lith. York

PLATE III.



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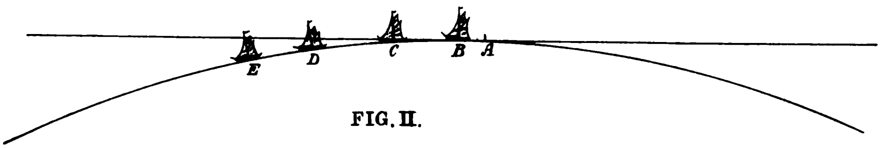

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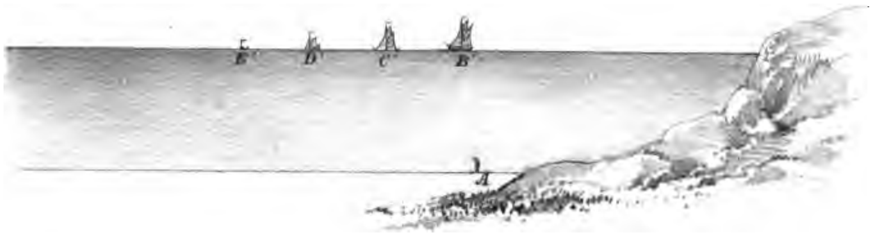

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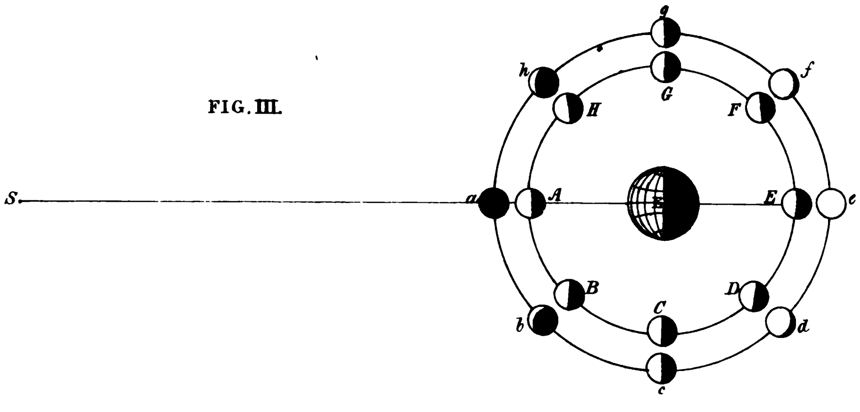

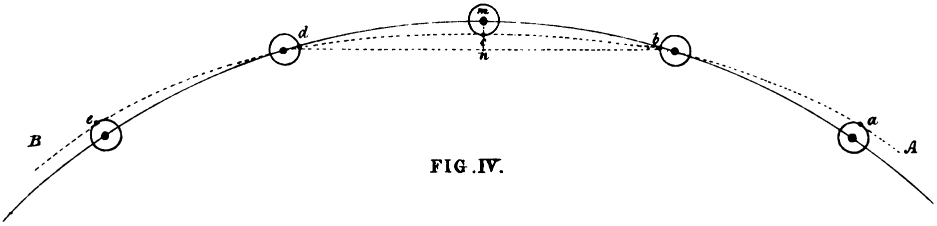

FIG. IV.

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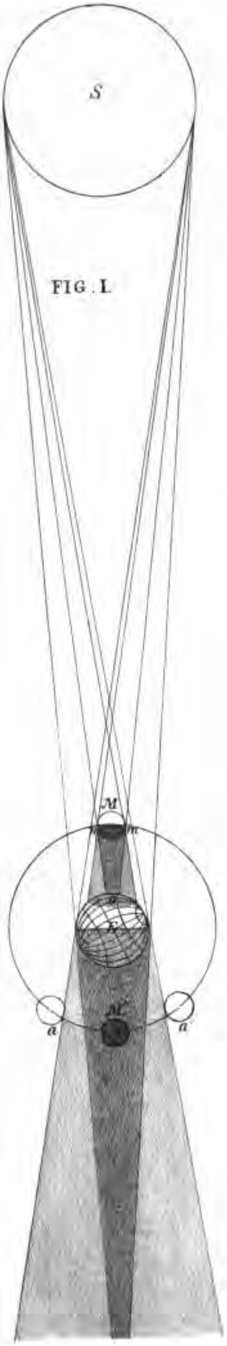
PLATE IV



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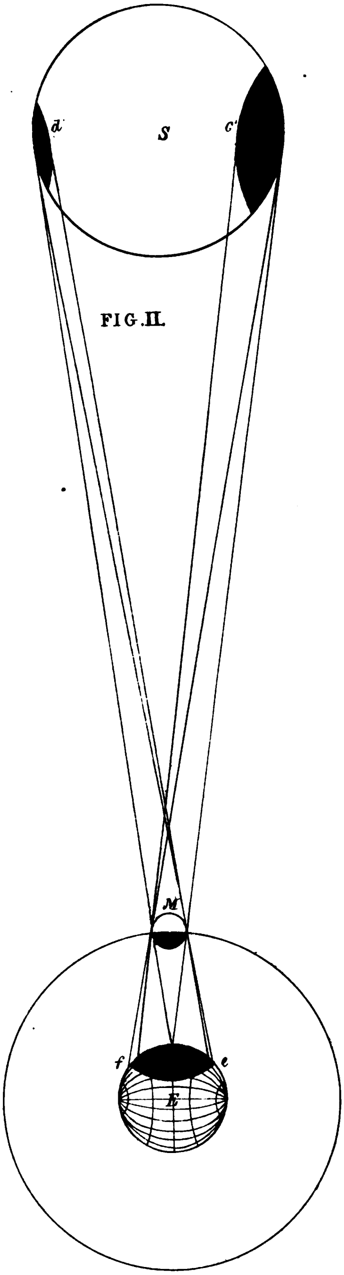
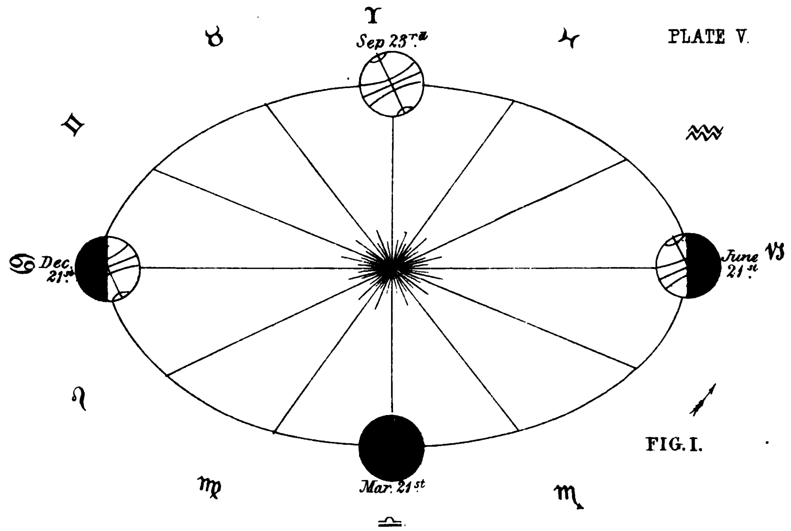


FIG. II.

W. Monkhouse, Lith York

PLATE V.



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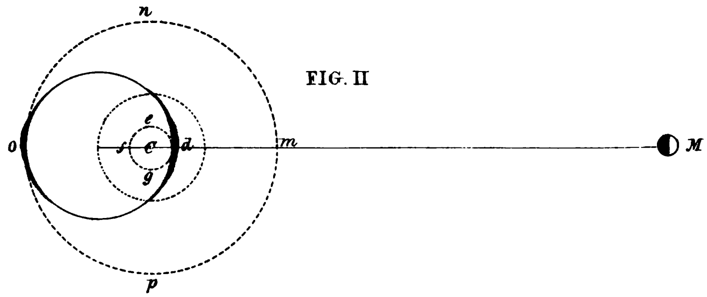

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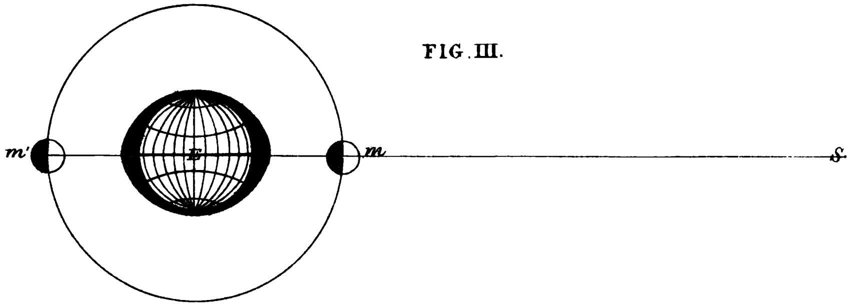

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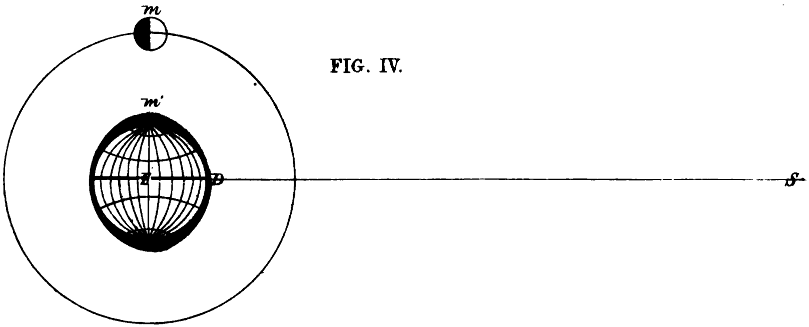

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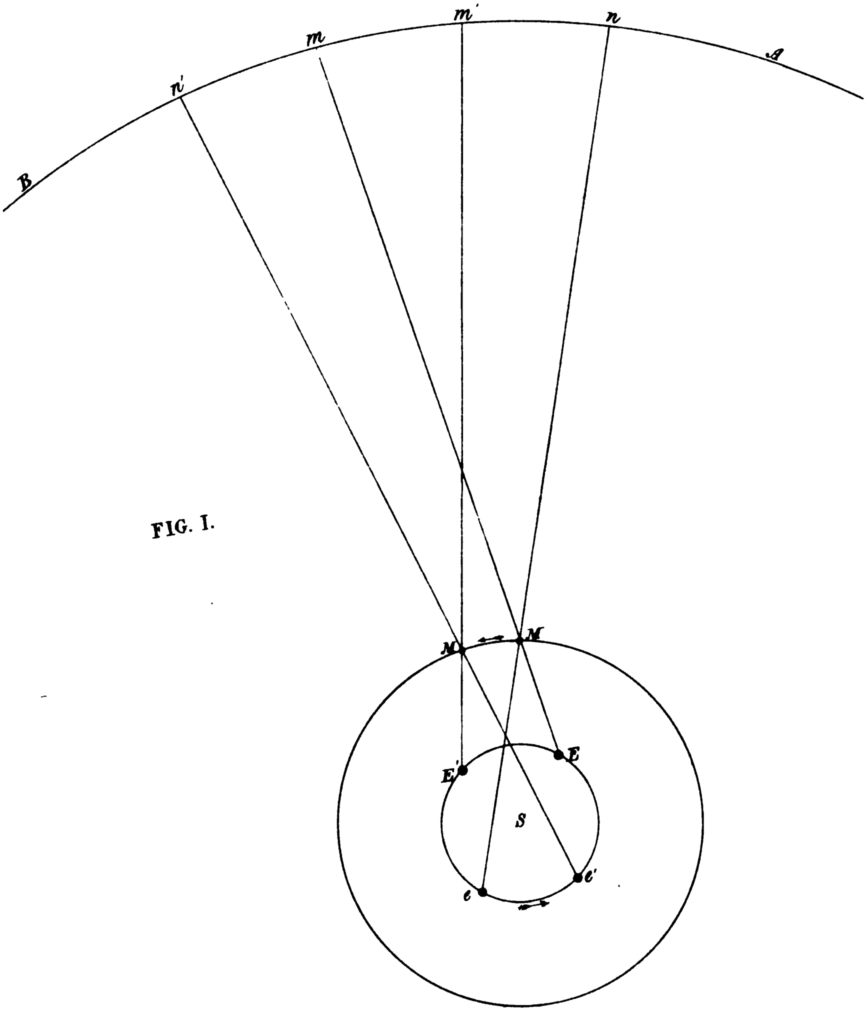

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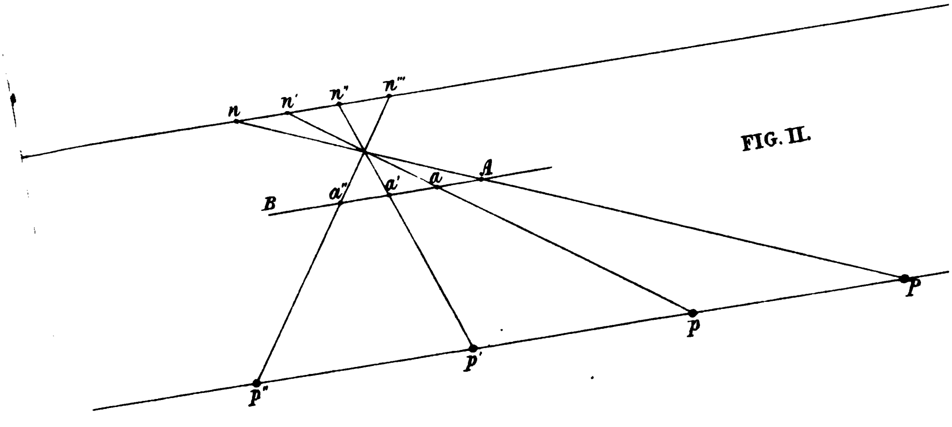

FIG. II.

PLATE VI.

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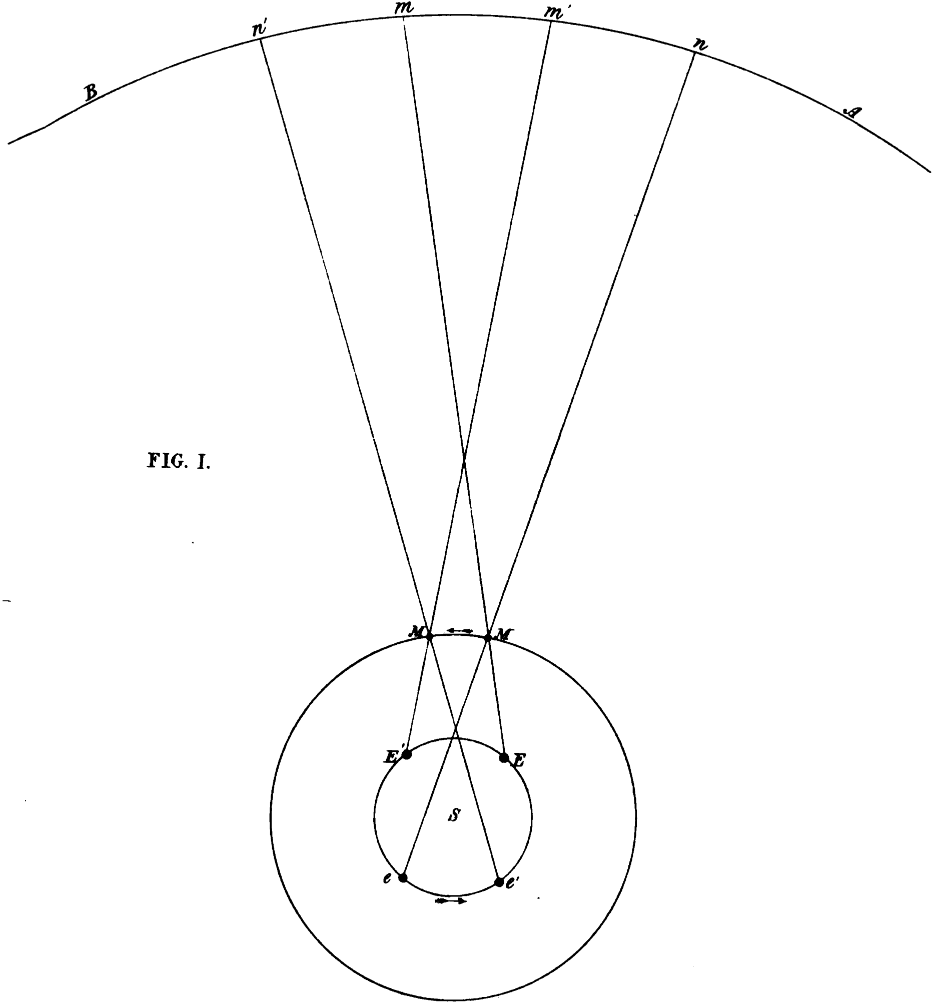

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